Chapter 9: Comprehensive Review of Invasive Exotic Species in the South Florida Environment

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SUMMARY

The widespread presence of invasive exotic species is one of the most serious environmental problems faced on a global scale. In 1993, the U.S. Congress Office of Technology Assessment reported that, of 630 listed threatened and endangered (plant and animal) species in the United States, 213 are listed primarily or exclusively due to losses caused by invasive exotic plants. In Florida, all information to date shows that exotic invasive plants and animals have taken an aggressive hold and that they are continuing to spread at an alarming rate. Currently, more than 31 percent of the plants found in Florida are non-native, as are over 26 percent of all animals.

Control of exotic invasive species is a far-reaching issue. The importance of this issue in restoration efforts is demonstrated by the extensive number of plans, reports, statements, and papers that have been written by numerous committees, state and federal agencies, public and private universities, state and federal task forces, and various other organizations. Most of these existing documents support an "all-taxa" approach. The general consensus of these parties is that control and management of nonindigenous species is a critical component of ecosystem restoration in South Florida.

This consensus was shared by the South Florida Ecosystem Restoration Task Force (SFERTF), which established the Noxious and Exotic Weed Task Team (NEWTT) to focus on South Florida's nonindigenous plants and the Florida Invasive Animal Task Team (FIATT) to focus on South Florida's nonindigenous animals. The NEWTT completed an assessment and a strategic plan for management of invasive exotic plant species, and is now working with the U.S. Army Corps of Engineers to develop a report on federal invasive species interests in Florida. The FIATT is developing a status report on exotic animals in South Florida. This report will be used as a basis for determining the extent of the problem, outlining agency responsibilities, and identifying interagency collaboration opportunities.

In 1996, under the direction of the Everglades Forever Act, the South Florida Water Management District (District or SFWMD) and several other state and federal agencies compiled a list of "Priority" invasive exotic plant species that are of the greatest threat to the Everglades. In July 2004, an "all taxa" interagency group was convened to increase the dialog between and among plant and animal specialists.

Many different techniques are used to control exotic invasive plants. Biological controls, herbicides, manual and mechanical controls, and cultural practices (such as prescribed burning and water level manipulation) are all used separately or in conjunction to slow the spread of exotic plants. While these different methods all have their strengths and weaknesses, biological control may offer the most cost-effective, long-term management approach for control of widespread invasive weeds. Standardized control methods for exotic animal species is extremely limited.

The Areawide Management and Evaluation (TAME) Melaleuca project, an interagency demonstration and implementation project funded by the U.S. Department of Agriculture - Agricultural Research Service and lead by the District, is successfully demonstrating integrated melaleuca management on public and private lands. It is hoped that this project will serve as a successful model for other species-based management plans.

In order to have future success with regard to both invasive plant and animal management, there must be commitment to funding and supporting research needs with an emphasis on invasive exotic species, biological controls, integrated management strategies, and the effects water level fluctuations on the spread of invasive species. Agencies must also continue to fund ongoing invasive species management programs, promote statewide agency coordination, develop comprehensive "all taxa" management authorities and regulations, and develop public/private partnerships.

The task of controlling exotic species — both animal and plant — cannot be addressed solely through one method or discipline, regulated by one authority, or controlled by one agency. The attack on invasive exotic species must be coordinated. Control of these species is a necessary component of all aspects of water resource management, whether for flood control, water supply, water quality, or natural resources.

INTRODUCTION

Invasive exotic species have become one of the most serious global environmental problems today (IUCN, 1999). A recent Cornell University study found that invasive species – plants, mammals, birds, amphibians, reptiles, fish, arthropods, and mollusks – cost the United States alone over $100 billion annually (Pimentel, 2000). Such losses and costs will inevitably continue to increase, especially if efforts to control these invasions are scattered. Planning, resources, and actions must be integrated effectively in order to turn back the overwhelming spread of numerous invasive species.

Florida is listed with Hawaii and California, and now Louisiana, as one of the states with the greatest number of exotic species. South Florida contains more introduced animals than any other region in the United States. With an estimated 26 percent of all resident mammals, birds, reptiles, amphibians, and fish not native to the region, South Florida has one of the largest exotic faunal communities in the world (Gore, 1976; Ewel, 1986; OTA, 1993; McCann et al., 1996; Shafland, 1996a; Simberloff, 1996; Corn et al., 1999). More than 30 years ago, a Smithsonian publication described tropical Florida as a "biological cesspool of introduced life" (Lachner et al., 1970).

INVASIVE EXOTIC SPECIES IN SOUTH FLORIDA

Control of exotic invasive species is a far-reaching issue. The importance of this issue in the Everglades Protection Area (EPA) is demonstrated by the great number of plans, reports, statements, and papers that have been written by numerous committees, state and federal agencies, public and private universities, state and federal task forces, and various other organizations. Most of the plans, reports, statements, and papers support an "all-taxa" approach. The general consensus of these parties is that control and management of invasive exotic species is a critical component of ecosystem restoration in South Florida.

The topic of invasive species has been identified as an issue since the beginning of the Everglades restoration initiative. Several organized efforts and mandates have highlighted the problems associated with exotic species in the Everglades region. Control and management of invasive exotics are the priorities established by the South Florida Ecosystem Restoration Task Force (SFERTF) in 1993. One of the tasks in the 1993 charter for the former Management Subgroup (December 16, 1993) was to develop a restoration strategy that addressed the spread of invasive exotic plants and animals. The U.S. Fish and Wildlife Service (USFWS) was designated as the lead agency for this strategy and submitted a brief report (Carroll, 1994). This report highlighted some of the following issues: (1) a limited number of species are designated as "nuisance" species and can be prohibited by law; (2) current screening processes are deficient; (3) responsibilities remain vague; (4) a general lack of awareness and knowledge of the harmful impacts of invasive species; and (5) an urgent need exists for statewide coordination and cooperation to eliminate exotics. The greatest obstacle to combating invasive exotic species, as identified in this report, is the lack of sufficient funding and manpower to stay ahead of problems.

The first Annual Report of the South Florida Ecosystem Restoration Working Group (SFERWG) in 1994 addressed all invasive exotic species, plants, and animals. The overall objectives stated were to (1) halt or reverse the spread of invasive species already widespread in the environment; (2) eradicate invasive species that are still locally contained; and (3) prevent the introduction of new invasive species to the South Florida environment. The Everglades Forever Act of 1994 (EFA) requires the South Florida Water Management District (SFWMD or District) to establish a program to monitor invasive species populations and to coordinate with other federal, state, and local governmental agencies to manage exotic pest plants, with an emphasis in the EPA.

The Scientific Information Needs Report (SSG, 1996) of the SFERTF contains a regionwide chapter on harmful invasive exotic species. One of the overall regional science objectives for the restoration is to develop control methods on exotic invasives at entry, distribution, and landscape levels. The specific objectives for work on invasive exotic species are to (1) halt and reverse the spread of invasive naturalized exotics, and (2) prevent invasions by new exotic species. The major issues in South Florida are inadequate funding for scientific investigations to develop effective controls, lack of funding to apply control methods to problem species, and delays and lack of consistency in responses to new problems. Most resources on exotic animals have been focused on agricultural pests, with little investigation of species that threaten natural areas. Particular information needs are as follows: (1) studies to develop control technology; (2) basic biological and ecological studies to improve understanding of invasive exotic species (e.g., how water management alterations will affect exotic plants and animals); (3) what are the principal controls on expansion of a species; (4) what are the impacts of invasive species on native species and ecosystems; (5) what makes a natural area susceptible to invasion; and (6) screening and risk assessment technology to help focus on the greatest potential problems. Overall, the major issue

is the lack of meaningful information concerning the effect of invasive exotic species in South Florida.

The Comprehensive Review Study Final Feasibility Report and Programmatic Environmental Impact Study (USACE and SFWMD, 1999) addresses the presence of exotic animals as one of several factors that preclude any serious consideration of achieving true restoration of the natural system, one in which exotic species are not present. It discusses how removal of canals and levees, which act as deepwater refugia for exotic fish and as conduits into interior marshes for other species, is expected to help control exotic species by slowing further movement into relatively pristine areas. On the other hand, restoration of lower salinity levels in Florida Bay might result in increases of reproductively viable populations of exotic fishes, such as the Mayan cichlid in the freshwater transition zone, and this must be addressed during detailed design.

The Department of the Interior's (DOI) Fish and Wildlife Coordination Act Report (FGFWFC, 1999) for the Comprehensive Everglades Restoration Plan (CERP) also considers control and management of exotic species as a critical aspect of ecosystem restoration in South Florida. The report discusses the effects of the present canal and levee system and of the preferred alternative of this system on the distribution of exotic animals. Some components of the Comprehensive Plan involve construction of canals and reservoirs, which could provide additional conduits from points of introduction into the Everglades for species such as fish, amphibians, and snails. Other components involve removal or partial removal of canals, a process which should reduce the spread of exotic fishes. Removal of levees, which act as artificial terrestrial corridors into the wetland landscape, should reduce the spread of species such as the fire ant. The DOI recommended establishment of an Exotic Animal Task Team to work on the issue during detailed planning for removal of existing structures or construction of new facilities as part of CERP. In relation to planned water preserve areas and flow-ways, it was recommended that an aggressive plan be developed for the perpetual removal of invasive exotics, both plants and animals. It was also recommended that existing control measures should be accelerated, more effective techniques should be developed, and regulations should be revised and better enforced to prevent additional introductions of exotic species (FGFWFC, 1999). The U.S. Army Corps of Engineers and the District (USACE and SFWMD, 1999) responded that in CERP this recommendation [team] should be presented to the South Florida Ecosystem Restoration Task Force.

Several other plans and reports also include exotic invasive species. The Coordination Act Reports (FGFWFC, 1999) from the Florida Game and Fresh Water Fish Commission (currently known as the Florida Fish and Wildlife Conservation Commission, or FWC) emphasize that the extent of the canal system's role in the spread of exotic fishes into natural marshes – as opposed to the fish remaining primarily in the disturbed areas – is debatable. The draft report, A New Look at Agriculture in Florida (Evans, 1999), discusses the introduction of exotic pests and diseases as a serious obstacle to sustainable agriculture and the importance of exclusion and control strategies. The South Florida Multi-Species Recovery Plan (USFWS, 1999a) identifies exotic animal control as a restoration need for two-thirds of the ecological communities and the individual species covered in the plan. In addition, the South Florida Regional Planning Council's 1991 and 1995 regional plans for South Florida list the removal of exotic plants and animals and discouragement of introductions as regional policies (SFRPC, 1991; 1995).

The Florida Department of Environmental Protection (FDEP) formed an Invasive Species Working Group (ISWG) in July 2001. Representatives from 13 state agencies and/or divisions and one state university comprise the ISWG. Jeb Bush, Governor of the State of Florida, charged this group with developing a comprehensive invasive species plan for state agencies. The plan is complete, and the group will begin implementation after it is accepted by the governor. In a

separate but complimentary program, FDEP also administers funding for invasive plant control efforts in Florida through regional working groups.

In 2002, the USACE authorized a conceptual plan for a multi-million dollar Invasive Species Management and Control project to be implemented as part of CERP. The main components of this project include cost-share agreements to improve quarantine facilities for biological control agents, a cost-share project with the SFWMD for the release of biocontrol agents, and preparation of a report to detail federal interest and potential federal involvement in invasive species projects within South Florida. As part of this effort, the USACE commissioned a report entitled "Filling the Gaps: Ten Strategies to Strengthen Invasive Species Management in Florida." This report, released by the Environmental Law Institute in August 2004, provides a comprehensive overview of the federal framework affecting invasive species management in Florida, with a particular focus on the Everglades. Although the recommendations are largely directed at federal agencies, they include steps that can be taken at all levels of government.

On a national level, the U.S. President's Executive Order on Invasive Species (Executive Order No. 13112) recognized the threats posed by invasive species and authorized a national invasive species council that would, among other duties, prepare a national management plan for invasive species. This plan was finalized and released in 2001. Implementation of this plan is ongoing through the National Invasive Species Council, which is chaired by the secretaries of agriculture, commerce, and the interior.

INVASIVE EXOTIC PLANT SPECIES

The South Florida Ecosystem Restoration Task Force and Working Group identified invasive exotic plants as a priority. As a result, the Noxious Exotic Weed Task Team (NEWTT) was established in 1997. NEWTT is a direct working team of the South Florida Ecosystem Restoration Task Force and Working Group and has two main directives. The first is the development of an assessment to characterize the current problems with invasive exotic plants in southern Florida and to identify the highest priority invasive species for control. The second directive calls for the development of a comprehensive interagency strategy for elimination or control of the highest priority species and for management to control and minimize the spread of other pest plant species.

The task team is made up only of government agencies – federal, state, and local. To comply with the Federal Advisory Committee Act and Florida's Sunshine Law, all NEWTT meetings are open to the public. While nongovernmental organizations (NGOs) are not an official part of NEWTT, the Florida Exotic Pest Plant Council (FLEPPC) provides advice and peer review to the task team.

The NEWTT developed a comprehensive strategic plan covering the issues and problems of exotic pest plants in Florida, with programmatic and management focus on the Everglades. However, a statewide perspective was used in developing this strategic plan, because any plan that addresses the issues of exotic pest plants cannot do so in a fragmented geographic or political framework. Federal, state, and local governmental policies affect, interact, and sometimes contradict one another, and therefore they must be addressed synthetically. In addition, the issues and experiences learned regionally (regarding control method development, research results, public education, technology transfer, policy, regulation, and funding) affect all agencies and programs throughout the state. Likewise, national-level issues related to exotic pest plants affect state and local policies and programs. The USACE has entered into an agreement with NEWTT to develop a report on federal invasive species interests in Florida.

INVASIVE EXOTIC ANIMAL SPECIES

The effort to address the issue of exotic animals in the Everglades has lagged behind that of invasive plants. While it is relatively easy to determine the extent to which exotic plants invade natural areas, the impact of exotic animals on native communities and on those species with which they compete directly is often less obvious (Schmitz and Brown, 1994). Several existing reports have highlighted this difficulty. According to the Multi-Species Recovery Plan (USFWS, 1999):

> It is probably safe to say that the most severe exotic species threats to the South Florida Ecosystem come from plants, rather than animals. Therefore, the emphasis on exotics in Florida has been on flora, rather than fauna.

The Scientific Information Needs Report (SSG, 1996) also addresses this problem as follows:

> The role of nonindigenous animals in South Florida natural areas is so poorly documented that it is difficult to design and mount an effective effort to control those that are harmful to native plant and animal communities.

Additionally, in Everglades, the Ecosystem and its Restoration, Robertson and Frederick (1994) bluntly state the following:

> Although biologists were quick to anticipate the developing problem, their concerns and pleas for regulation have been thoroughly overrun by events…Any present attempt to assess the overall threat posed by nonnative animals to the integrity of the Everglades ecosystem seems futile…In addition, thought may tend to become paralyzed by the obvious, perhaps insurmountable, difficulty of effective countermeasures.

In spite of these daunting conclusions, the SFERTF Working Group has been gathering information that is available as a basis for an assessment of the problem. In February 1998, the Working Group established an ad hoc interagency team to (1) focus on South Florida and evaluate the status of exotic animals in all habitats (freshwater, marine, and terrestrial), (2) describe efforts underway to deal with them, and (3) identify agency needs and problems (Goodyear, 2000).

The SFERTF established a Noxious Exotic Animal Task Team (NEATT) in 2003 (Note that this name has since been changed to the Florida Invasive Animal Task Team, or FIATT). This group convened and is developing a nonnative animal report to provide a broad picture of the status of exotic animal species in South Florida. It will focus on the agencies, along with their respective departments, that are represented on the SFERTF Working Group. This report is to be used as a basis for the SFERTF Working Group to evaluate its members' priorities relative to exotic animals and to determine if and how it might assist the work of individual agencies, enhance interagency collaboration, and integrate South Florida efforts into state, regional, or national programs.

In July 2004, the District and the DOI jointly convened an Everglades Invasive Species Summit in an effort to increase dialog between and among plant and animal specialists. The group presented new information about various taxa and discussed priority exotic species in the Everglades.

MARINE INVASIONS

The extent of exotic species invasions into marine habitats of Florida are not well documented, although the pathways for this invasion are clear. The sources include accidental releases from an expanding aquaculture industry (especially tropical fish), home aquaria releases, live seafood escapes, and shipping ballast and fouling water releases. Marine habitats are less visible, and documenting marine system impacts has been poor. Marine invasions are not a new issue to North America. Shipworms were spread around the globe by early explorers (pre-Columbus), and green crabs were first reported in the United States waters in the early 1850s. Rates of introductions are increasing with the rate of increased ship traffic. It is estimated that ship ballast water transports between 3000 to 7000 foreign species daily around the globe. With 80 percent of the world's commodities carried by ship, the probability of new species introductions and subsequent establishment is high. A 2002 report documenting invasive species in Florida's saltwater systems reported 40 species of exotic species as having established populations. Marine scientists believe the actual numbers are much higher. The exotic species established in Florida marine environments include 9 fishes, 3 mollusks, and 12 crustaceans. Since the publication of this report, the Florida Marine Research Institute confirmed that the red lionfish (*Pterois volitans*) is now established along Florida's Atlantic Coast. A foreign marine algae (*Caulerpa brachypus*) has also recently established along Florida's Southeast Atlantic Coast. This algal species is native to the Pacific Ocean. *C. brachypus* was first discovered off the coast of Palm Beach County, and is spreading north and south. This algae is widespread in waters 65 to 140 feet deep and is growing over and displacing other macroalgae, sponges, and corals.

MANAGEMENT EFFORTS

The District has been closely coordinating all vegetation management efforts with other agencies within the Everglades Protection Area since 1990. This close coordination has resulted in detailed, species-based management plans (Melaleuca Management Plan, Brazilian Pepper Management Plan, Lygodium Management Plan) and a maximization of all available management resources. In addition, the District has been required since 1979 to get permits from the FDEP for all vegetation management activities in public waters. The permit process has helped to bring peer review as well as statewide consistency to management approaches. Within the EPA, floating aquatic plant control in canals has been coordinated with the USFWS and the Everglades National Park (ENP or Park) since the early 1970s. Specifically, this relates to water hyacinth and water lettuce spraying and/or harvesting in and around the S-10 and S-12 structures and within the L-7, L-39, L-40, and L-29 canals. Currently, the District does not have dedicated staff or funding to coordinate efforts and control invasive exotic animals in South Florida.

MANAGEMENT AUTHORITIES

There are a number of local, state, and federal statutes and rules that govern the activities of vegetation management programs in Florida. The most pertinent of these are summarized below.

District Regulations

- Developed from the maintenance considerations of the Flood Control Act of 1948, House Document 643, 80th Congress, 2nd Session and Chapters 25270 and 378, Florida Statutes (F.S.), 1949, which provide for maintenance of project works necessary for flood protection and water supply.

State of Florida Regulations

- *Chapter 62C-54, F.A.C., FDEP Funding for Aquatic Plant Management* – The State of Florida and the USACE provide funds through the Aquatic Plant Management Trust Fund to water management districts and local governments to implement maintenance programs for the management of aquatic plants. After federal and state appropriation, the USACE and the Florida Legislature provide funds to FDEP annually for this purpose. Funds are allocated by FDEP to grant applicants, after evaluation of work plan and budget requests submitted for eligible waters, in accordance with eligibility standards and priorities established in this chapter. The department then monitors and assists grantees to ensure the appropriate management of aquatic plants and funds. Acceptable herbicide, mechanical and physical, and biological control management standards are described.

- *Chapter 212.69 F.S., Distribution of Proceeds* – The FDEP shall be transferred $3.8 million per year in equal monthly amounts from the Gas Tax Collection Trust Fund, which shall be used for eradication or control and research of water hyacinth and noxious aquatic vegetation. Also, $1 million shall be spent solely for
  non-chemical control of aquatic weeds, research into non-chemicals, and enforcement of aquatic weed control programs.

- *Chapter 327.28 F.S., Aquatic Plant Control Trust Fund (Motor Boat Revolving Trust Fund; Appropriation and Distribution)* – Two dollars from each non-commercial vessel registration fee, except for Class A-1 motorboats, shall be transferred to the Aquatic Plant Control Trust Fund for aquatic weed research and control. Forty percent of the registration fees from commercial vessels shall be transferred to the Aquatic Plant Control Trust Fund for aquatic plant research and control.

- *Chapter 369.20 F.S., Florida Aquatic Weed Control Act* – The FDEP will direct the control, eradication, and regulation of noxious aquatic weeds and the research and planning related to these activities. They will guide and coordinate the activities of all public bodies, authorities, agencies and special districts charged with the control or eradication of aquatic weeds and plants; promote, develop, and support research activities directed toward the more effective and efficient control of aquatic plants; and disburse funds to any special district or other local authority charged with the responsibility of controlling or eradicating aquatic plants, under certain conditions.

- *Chapter 369.22 F.S., Nonindigenous Aquatic Plant Control* – Delegates the responsibility of supervising, directing, guiding, reviewing, approving, coordinating, and disbursing of funds for the control of nonindigenous aquatic plants, excluding the authority to use fish as a biological control agent. This defines terms relating to nonindigenous aquatic plant control and designates areas of state and local responsibilities (e.g.intercounty waters [state] and intracounty waters [local]). Annual status report of the nonindigenous aquatic plant maintenance programs in intercounty waters will be provided by January 1st to the Governor and Cabinet. Authorizes the FDEP to enter into cooperative agreements with the United States and delegates authority to the FWC, as necessary.

- *Chapter 369.25 F.S., Aquatic Plants; Permits; Penalties* – Requires a person engaging in the business of importation, transportation, cultivation, collection, sale, or possession of any aquatic plant species to obtain a permit or exemption from the FDEP. No person shall import, transport, cultivate, collect, sell, or possess any noxious aquatic plant listed on the prohibited aquatic plant list established by the state without a permit or exemption issued by the FDEP. This act provides the FDEP certain powers, which are to: (1) make rules governing the importation, transportation, cultivation, collection, and possession of aquatic plants; (2) establish by rule lists of aquatic plant species regulated in coordination with the Florida Department of Agriculture and Consumer Services (FDACS) and the FWC; (3) evaluate aquatic plant species through research; (4) declare quarantine; (5) make rules governing the application process; (6) enter into cooperative agreements with any person to carry out this act; (7) purchase all necessary supplies, material and equipment necessary; (8) enter upon and inspect any aquatic plant facility to determine compliance with this section and Department regulations and to seize and destroy, without compensation, any aquatic plants held in violation of these provisions; and (9) conduct a public information program. Violations of the provisions of this act are punishable as a second-degree misdemeanor.

- *Chapter 369.251 F.S., Invasive Nonnative Plants; Prohibitions; Study; Removal; Rules* – Prohibits the selling, transporting, collecting, cultivating, or possessing any plant, including any part or seed, of the species *Melaleuca quinquenervia, Schinus terebinthifolius, Casuarina equisetifolia, C. glauca,* or *Mimosa pigra* without a permit from the FDEP. Also directs FDEP to study methods of control of these plants as well as to adopt rules to implement this section. This statute specifically directs the South Florida Water Management District to undertake programs to remove such plants from Water Conservation Areas 1, 2, and 3 (WCA-1, 2, and 3).

- *Chapter 369.252 F.S., Invasive Exotic Plant Control on Public Lands* – Directs FDEP to establish a program to (1) achieve eradication or maintenance control of invasive exotic plants on public lands; (2) assist state and local government agencies in the development and implementation of coordinated management plans for the eradication or maintenance control of invasive exotic plant species on public lands; (3) contract, or enter into agreements, with entities in the State University System or other governmental or private sector entities for research concerning biological control agents; and development of workable methods for the eradication or maintenance control of invasive exotic plants on public lands; and (4) use funds in the Invasive Plant Control Trust Fund for carrying out activities on public lands. Twenty percent of the funds shall be used for the purpose of controlling nonnative, upland, invasive plant species on public lands.

- *Chapter 370.021 F.S., Administration; Rules, Publications, Records; Penalty for Violation of Chapter; Injunctions* – Ensures that the FDEP shall make, adopt, promulgate, amend and repeal all rules and regulations necessary or convenient for the carrying out of the duties, obligations, powers, and responsibilities conferred on the Department or any of its divisions.

- *Chapter 403.088 F.S., Water Pollution Operation Permits; Temporary Permits; Conditions* – This act directs the FDEP to establish the procedures for programs

to issue permits for aquatic plant control activities as they may affect water quality in waters of the state.

- *Chapter 403.141 F.S., Civil Liability: Joint and Several Liability* – A violator would be required to restore the natural resources to its former condition and would be subject to the judicial imposition of a civil penalty up to $10,000 per offense. Each violator shall be jointly and severally liable for such damage and for the reasonable cost and expenses incurred by the state. A table of values for individual categories of fish is determined by the FDEP and the FWC to be utilized in the assessment of damages for fish killed. This act also provides for exemption of damages for fish kills caused by approved aquatic plant control. The laws of Chapter 403, F.S. pertain to Chapters 17-3 and 17-4, Florida Administrative Code (F.A.C.).
- *Chapter 403.161 F.S., Prohibitions, Violations, Penalty, Intent* – Provides for civil and criminal penalties and fines for any violation of Chapter 403, F.S. A fine of $2,500 or no more than $25,000 or one year in jail, or both, is provided for each offense. Violations discovered under the rules of Chapter 62C-20, F.A.C. are reported to the FDEP for processing.

Federal Regulations

Several acts provide the USACE a congressional mandate for responsibility for funding and management of navigable waters of the Unites States. Specifically mentioned is the removal of obstructions to navigation, maintenance of waterways in the interest of flood control, maintenance and improvement of water resources development projects, and conservation of natural resources held in public trust. These federal acts include the following:

- Rivers and Harbors Act of 1899, Section 10, 33 U.S.C. Section 403 (1986)
- Flood Control Act of 1944, Section 2, 33 U.S.C.A. Section 701a-1 (Supp. 1988)
- Flood Control Act of 1944, Section 4, 58 Statute 889 [codified as amended at 16 U.S.C., Section 460d (1974 and Supp. 1988)]
- Forest Cover Act, Sections 1 and 2, of 1960, 16 U.S.C., Sections 580m–n (1985)
- Fish and Wildlife Coordination Act, Section 2, of 1958, 72 Stat. 5639 (codified as amended at 16 U.S.C., Sections 661-664, 1985 and Supp. 1988)
- 31 U.S.C., Section 6305 (1983)

PERMITTING

All vegetation management activities are permitted and governed under several federal and state regulations. The FDEP's Bureau of Invasive Plant Management is the lead agency for the permitting of activities as well as inspection and enforcement of regulations. The FWC and the FDEP's Division of Environmental Resource Permitting review all permit applications. This review process results in the approval, disapproval, or modification of the application activities. A listing of the various state and federal laws and rules is summarized below.

State of Florida Permitting

- *Florida Pesticide Law and Rules, Chapter 487,F.S. and Chapters 5E-2 and 5E-9, F.A.C.* – Provides for the state administration of Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) according to a specific plan approved by the USEPA, application for Special Local Needs (SLN) permits, and certification standards for applicators.
- *FDEP Permitting Rule, Chapter 62C-20, F.A.C.* – Provides for the protection of the waters of the State from uncontrolled growth of aquatic vegetation through a program of contracts and permits. Establishes types of permits, criteria for operational programs, and penalties.
- *FDEP Permitting Rule, Chapter 62C-52, F.A.C.* – Provides for the protection of the waters and the native aquatic and wetland vegetation communities of the State by regulating and permitting the collection, transportation, possession, cultivation, sale, and planting of selected plant types.
- *FDACS Rule, 5B.–57.006 and 57.007* – States that it is unlawful to introduce, possess, move, or release any living stage of designated prohibited plants without a permit. It also provides that FDACS shall cooperate with other appropriate parties to eradicate or control noxious weeds.
- *FWC Permitting Rule, 68A-23.088.* – Provides for the utilization of triploid grass carp in public and private waters of the state.

Federal Permitting

- *The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), Public Law 92-516 of 1972 (as amended)* – Provides for the federal registration of pesticides, certification of applicators, regulation of restricted use pesticides, record keeping, protection of trade secrets, unlawful acts and penalties, disposal and transportation, and administrative procedures relating to pesticides.
- *Noxious Weed Regulations, Part 360, 7 U.S.C. 2803 and 2809; 7 CFR 2.17, 2.51, and 371.2(c)* – Contains definitions, the list of federal noxious weeds, and general prohibitions and restrictions on the movement of federal noxious weeds.

INVASIVE PLANT MANAGEMENT TOOLS

Many different techniques are used to control exotic invasive plants within the Everglades Protection Area. Biological controls, herbicides, manual and mechanical controls, and cultural practices (such as prescribed burning and water level manipulation) are used separately or in conjunction to slow the spread of exotics. Following are more detailed descriptions of each of these methods. Specific species-level controls are discussed in the "Priority Species" section below.

Biological Control

Plants are often prevented from becoming serious weeds in their native range by a complex assortment of insects and other herbivorous organisms. When a plant is brought into the United States, the associated pests are thoroughly screened by government regulations on plant pest

importation. Favorable growing conditions and the absence of these associated pest species have allowed some plants to become serious weeds outside their native range.

"Classical" biological control seeks to locate such insects and import host-specific species to attack and control the plant in regions where it has become a weed. The classical approach has a proven safety record (none of the approximately 300 insect species imported specifically for this purpose have ever become pests themselves) and has been effective in controlling almost 50 species of weeds.

The following are the performance steps of a classical biological control investigation:

1. Identify the target pest and prepare a report outlining the problem conflicts, potential for a successful program, etc.
2. Survey and identify the pest's native range for a list of herbivores that attack the pest plant
3. Identify the best potential biocontrol agents based on field observations, preliminary lab tests, and information from local scientists
4. Conduct preliminary host-range tests on the most promising candidate in the native country in order to obtain permission to import to U.S. quarantine
5. Complete host-range tests in U.S. quarantine to ensure the safety of the organism relative to local native plants, agricultural crops, and ornamentals
6. Petition the Technical Advisory Group of the U.S. Department of Agriculture (USDA) for permission to release into the United States. Also, obtain permission from necessary state agencies
7. Culture agents that are approved to have sufficient numbers to release at field sites. Test release strategies to determine the best method
8. Monitor field populations of pest plants to:

   a) Determine if biocontrol agent establishes self-perpetuating field populations

   b) Understand plant population dynamics to have a baseline to measure bioagent effects, especially if they are sublethal and subtle, and to know what portions of life history to watch
9. Study effectiveness of the agents for controlling the target plant. Monitor plant populations with and without the agent to determine impacts of the agent
10. Study means of integrating biocontrol into overall management plans for the target plant

In Florida, classical biological control of invasive nonnative plants in nonagricultural areas has focused on aquatic weeds. The first such biocontrol agent introduced was the alligatorweed flea beetle (*Agasicles hygrophila*) in 1964 for control of alligatorweed (*Alternanthera philoxeroides*). Subsequently, the alligatorweed thrips (*Aminothrips andersoni*) was released in 1967 and the alligatorweed stem borer (*Vogtia malloi*) in 1971. The flea beetle and stem borer proved to be fairly effective for suppressing growth of alligatorweed, although harsh winters can reduce their populations. Less effective have been introductions of the water hyacinth weevils (*Neochotina eichhorniae* and *N. bruchi*), released in 1972 and 1974, and the water hyacinth borer, released in 1977 (*Sameodes albigutalis*) for water hyacinth control. Likewise, effectiveness of a weevil (*Neohydronomous affinis*) and a moth (*Namangama pectinicornis*) released for control of water lettuce has been unpredictable. Water hyacinth and water lettuce continue to require management by other methods, such as herbicide and mechanical harvesting. Current biological

control research is focused on hydrilla, water hyacinth, melaleuca, Brazilian pepper, and Old World climbing fern.

Melaleuca snout beetles are damaging melaleuca stands and are showing signs of range expansion after initial releases in 1997. The second melaleuca agent (a psyllid) was released in April 2002. Approval for the release of the first *Lygodium* insect (a moth) was received in August, 2004. The first Brazilian pepper insect and additional melaleuca-damaging insects may be approved for release in Florida soon. Overseas surveys and host-specificity screening for additional agents is ongoing.

Introduction of animals such as cattle, sheep, goats, or weed-eating fish may also be used to control certain invasive plants. However, environmental impacts of using such nonselective herbivores in natural areas should be carefully considered before implementation.

Herbicides

Herbicides are pesticides designed to control plants. They are a vital component of most control programs and are used extensively for exotic plant species management in South Florida.

Herbicide Application Methods

- *Foliar applications* – A herbicide is diluted in water and applied to the leaves with aerial or ground equipment. Foliar applications can either be directed, to minimize damage to nontarget vegetation, or broadcast. Broadcast applications are used where damage to nontarget vegetation is not a concern or where a selective herbicide is used.
- *Basal bark applications* – A herbicide is applied, commonly with a backpack sprayer, directly to the bark around the circumference of each stem/tree up to 15 inches above the ground.
- *Frill or girdle (sometimes called hack-and-squirt) applications* – Cuts into the cambium are made completely around the circumference of the tree, with no more than 3-inch intervals between cut edges. Continuous cuts (girdle) are sometimes used for difficult-to-control species and for large trees. Herbicide (concentrated or diluted) is applied to each cut until the exposed area is thoroughly wet. Frill or girdle treatments are slow and labor intensive, but they are sometimes necessary in mixed communities to kill target vegetation and to minimize impact to desirable vegetation.
- *Stump treatments* – After cutting and removing large trees or brush, a herbicide (concentrated or diluted) is sprayed or painted onto the cut surface. The herbicide is usually concentrated on the cambium layer on large stumps, especially when using concentrated herbicide solutions. The cambium is next to the bark around the entire circumference of the stump. When using dilute solutions, the entire stump is sometimes flooded (depending on label instructions) with herbicide solution.
- *Soil applications* – Granular herbicide formulations are applied by handheld spreaders, by specially designed blowers, or aerially.

Where Herbicides Can Be Used

A pesticide, or some of its uses, is classified as restricted if it could cause harm to humans or to the environment unless it is applied by certified applicators who have the knowledge to use the pesticide safely and effectively. Although none of the herbicides commonly used for invasive plant control in the Everglades is classified as restricted-use, the basic knowledge of herbicide technology and application techniques that are needed for safe handling and effective use of any herbicides can be obtained from restricted-use pesticide certification training. All District applicators and contractor supervisors are required to obtain and maintain this certification before applying herbicides in the Everglades Protection Area.

No pesticide can be sold in the United States until the USEPA has reviewed the manufacturer's application for registration and has determined that the use of the product will not present unreasonable risk to humans or to the environment.

The USEPA approves use of pesticides on specific sites, i.e., for use on individual crops, terrestrial non-crop areas, or aquatic settings. Only those herbicides registered by the USEPA specifically for use in aquatic sites can be applied to plants growing in lakes, rivers, canals, etc. For terrestrial uses, the USEPA requires herbicide labels to have the following statement: "Do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high-water mark." Rodeo® is registered for aquatic use and can be applied directly to water. Certain, but not all, products that contain 2,4-dichlorophenoxyacetic acid (2,4-D) can also be applied directly to water. The state supplemental "special local need" (SLN) label for the imazapyr-containing product, Arsenal® (USEPA SLN No. FL-940004) allows government agencies and their contractors to use it to control melaleuca and Brazilian pepper growing in water.

Herbicide Toxicity to Wildlife

Invasive plant management is often conducted in natural areas to maintain or restore wildlife habitat. Therefore, it is essential that the herbicides are not toxic to wildlife. Herbicides used for invasive plant control in the Everglades have shown very low toxicity to the wildlife they have been tested on, with the exception of the relatively low LC50 (Lethal Concentration, 50%) of triclopyr ester (0.87 parts per million, or ppm) and fluazifop (0.57 ppm) for fish, neither of which can be applied directly to water. Ester formulations are toxic to fish because of irritation to fishes' gill surfaces. However, because triclopyr ester and fluazifop are not applied directly to water, are adsorbed by soil particles, and have low persistence, exposure is low, which results in low risk when properly used.

Manual and Mechanical Removal

Manual removal is very time consuming, but it is often a major component of effective invasive plant control. Seedlings and small saplings can sometimes be pulled from the ground, but even small seedlings of some plants have tenacious roots that will prevent extraction or cause them to break at the root collar. Plants that break off at the ground will often resprout, and even small root fragments left in the ground may sprout. Repeated hand pulling or follow-up with herbicide applications are often necessary. Removal of uprooted plant material is important. Stems and branches of certain species (e.g., melaleuca) that are left on the ground can sprout roots, and attached seeds can germinate. If material cannot be destroyed by methods such as burning, then it should be piled in a secure area that can be monitored, and new plants should be killed as they appear.

Mechanical removal involves the use of bulldozers or of specialized logging equipment (to remove woody plants). Intense follow-up with other control methods is essential after the use of heavy equipment, because disturbance of the soil creates favorable conditions for regrowth from seeds and root fragments as well as recolonization by invasive nonnative plants. Mechanical removal may not be appropriate in natural areas because of the disturbance to soils and nontarget vegetation caused by the heavy equipment.

In aquatic environments, mechanical controls include self-propelled harvesting machines, draglines, cutting boats, and other machines, most of which remove vegetation from the water body. These systems generally are used for clearing boat trails, high-use areas, or locations where immediate control is required, such as for flood control canals and around water control structures.

Cultural Practices

Prescribed burning and water level manipulation are cultural practices that are used in management of pastures, rangeland, and commercial forests. In some situations they may be appropriate for vegetation management in natural areas. Land use history is critical in understanding the effects of fire and flooding on the resulting plant species composition. Past practices may have affected the soil structure, organic content, seed bank (both native and invasive exotic species), and species composition. While there is evidence that past farming and timber management practices will greatly influence the outcome of cultural management, very little is known about the effects of specific historical practices. Similar management practices conducted in areas with dissimilar histories may achieve very different results. Even less is known about the effects of invasives entering these communities or about the subsequent management effects of fire on the altered communities.

Understanding the reproductive biology of the target and nontarget plant species is critical to effective use of any control methods, but it is particularly true with methods such as fire management, which often require significant preparation time. Important opportunities exist when management tools can be applied to habitats where nonnative invasive species flower or set seed at different times than the native species.

Prescribed Burning

Fire is a normal part of most of Florida's ecosystems, and as a result native species have evolved varying degrees of fire tolerance. Throughout much of the Everglades, suppression of fire has altered historical plant communities. Within these communities, the fire-tolerant woody species have lingered in smaller numbers, and less fire-tolerant species have replaced ephemeral herbs. Little is known about the amount, frequency, timing, and intensity of fire that would best enhance the historically fire-tolerant plant species. Even less is known about how such a fire management regime could be best used to suppress invasive species. Single fires in areas with many years of fire suppression are unlikely to restore historical species composition. Periodic fires in frequently burned areas do little to alter native species composition.

Invasion of tree stands by exotic vines and other climbing plants – such as Old World climbing fern on Everglades tree islands – has greatly increased the danger of canopy (crown) fires and the resulting death to mature trees. The added biomass by invasive plants can result in hotter fires and can greatly increase the risk of fires spreading to inhabited areas. In these situations, use of fire to reduce standing biomass of invasive species may better protect the

remaining plant populations than by doing nothing, even though impacts to nontarget native species will occur.

Water Level Manipulation

Some success has been achieved by regulating water levels to reduce invasive plant species in aquatic and wetland habitats. De-watering aquatic sites reduces standing biomass, but little else is usually achieved unless the site is rendered less susceptible to repeated invasion when rewatered. Planting native species may reduce the susceptibility of aquatic and wetland sites in some cases.

In most situations, water level manipulation in reservoirs has not provided the level of invasive plant control that was once thought achievable. Ponds and reservoirs can be constructed with steep sides to reduce invaded habitat, and levels can be avoided that promote invasive species, but rarely are these management options adaptable to natural areas.

Carefully timed water level increases following herbicide treatments, mechanical removal, or fire management of invasive species can sometimes control subsequent germination, and, with some exotic species, resprouting.

PRIORITY SPECIES

MELALEUCA (*Melaleuca quinquenervia*)

Melaleuca trees were introduced to Florida in the early 1900s (Fairchild, 1947) and seed was scattered aerially over the Everglades in the 1930s to dry up "useless swampland" (Austin, 1978). It is hardy and fast-growing. These characteristics spurred its use as an ornamental landscape tree, as agricultural windrows and protective living "guard rails," and as soil stabilizers along canals. Melaleuca was recommended as late as 1970 as "one of Florida's best landscape trees" (Watkins, 1970).

Melaleuca readily invades canal banks, pine flatwoods, cypress swamps, and uninterrupted sawgrass prairies of South Florida (Myers, 1975; Austin, 1978; Woodall, 1981b and 1982; Duever et al., 1986; Nelson, 1994). It grows extremely fast, producing dense stands that displace native plants, diminish animal habitat, and provide little food for wildlife (Laroche and Ferriter, 1992).

Melaleuca prefers seasonally wet sites, but it also flourishes in standing water and well-drained uplands (Laroche, 1994b). Saplings are often killed by fire, but mature trees can survive fire and severe frost damage (Woodall, 1981). Melaleuca grows 1 to 2 meters per year, resprouts easily from stumps and roots, and is capable of flowering within two years from seed (Laroche, 1994b). Melaleuca flowers and fruits all year, producing up to 20 million windborne seeds per year per tree. It is able to hold viable seed for a massive all-at-once release when stressed (Woodall, 1983). Melaleuca releases volatile oils into the air, especially when blooming, which cause respiratory irritation, asthma attacks, headaches, and/or rashes in some people (Morton, 1971b).

Melaleuca has been found naturalized in Florida as far north as Hernando, Lake, and Brevard counties (Mason, 1997; Wunderlin et al., 2000). It is reported from natural areas in 16 Central and South Florida counties (EPPC, 1996). Melaleuca grows equally well in the deep peat soil of

WCA-1 and in the inorganic, calcareous soil of the Everglades National Park. In general, wetland areas such as sawgrass prairie are more susceptible than drier, upland areas.

Before state and federal control operations were initiated in 1990, melaleuca was distributed throughout South Florida. Pioneering or "outlier" melaleuca had invaded the interior of the Park and WCA-2A. Light to moderate infestations occurred in WCA-3 and the western edge of the East Everglades Acquisition Area. Moderate to heavy infestations occurred in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Refuge), Big Cypress National Preserve, WCA-2B, Lake Okeechobee, and wetlands in Miami-Dade, Broward, Lee, and Collier counties. Baseline surveys in the early 1990s showed that melaleuca had invaded approximately 197,640 hectares in South Florida (Ferriter, 1999b).

There are differing perspectives on the role of melaleuca in South Florida. Melaleuca's potential spread in South Florida is considered by some experts to be unlimited, ultimately encroaching on all open land (Hofstetter, 1991a). Others believe it will be limited to underutilized niches in the relatively young Florida landscape (Myers, 1975). Yet both views share a common thread: melaleuca needs to be controlled, whether or not it could ultimately cover the peninsula.

The District's efforts to control melaleuca, along with those of other governmental agencies and private groups, are succeeding in containing its spread on public conservation lands. Melaleuca has been completely cleared from WCA-2A, 3A, and 3B, north and south of Alligator Alley, and from the marsh in Lake Okeechobee. These areas are now under "maintenance control." Today, the melaleuca infestation on SFWMD managed lands is no longer increasing; in most areas, it has been significantly reduced.

The goal of the current melaleuca management program is to contain melaleuca on all District-managed lands and to maintain infestation levels as low as possible while minimizing impacts to non-target vegetation. The operational and experimental work accomplished to date demonstrates melaleuca can be effectively and consistently controlled using an integrated pest management (IPM) approach. IPM combines management tools (i.e., herbicide, mechanical/manual, biological controls and physical methods) to provide better melaleuca control than any one tool could achieve alone. The ultimate control of melaleuca throughout the District will depend primarily on the future availability of funds. The magnitude of the threat of melaleuca and the cost of current control efforts are enormous.

The integrated pest management of melaleuca requires a combination of control techniques to be effective. The District's efforts in developing melaleuca control methods have been concentrated around herbicidal control and the limited use of mechanical and physical control methodologies. Aerial application of herbicide has become essential and is now widely used for treatment of large areas of melaleuca monocultures where threats to non-target vegetation are minimal. In sparse areas of melaleuca, various ground control methods are used including frill and girdle and cut/stump applications of herbicide to kill mature trees, hack and squirt applications for saplings, and manual removal (hand-pulling) of seedlings to minimize the impact of herbicides on non-target vegetation. Under ideal conditions, melaleuca can be eliminated from an area within two years. The first phase of control targets all existing trees and seedlings in a given area. Using navigational equipment, the second phase consists of crews returning to the same site to remove any seedlings resulting from the control activities of the previous year. The third phase entails the long-term management of melaleuca, surveillance and inspection of previously treated sites to monitor the effectiveness of the melaleuca control program and maintain re-infestation levels as low as possible.

A key component of an effective and long-lasting melaleuca management program is the introduction of biological control (biocontrol) agents. Without biological control, melaleuca elimination will be much more expensive and could not be truly integrated. The first biocontrol release for melaleuca was the melaleuca snout beetle (*Oxyops vitiosa*) in April 1997. More than 18,000 larvae and 210,000 adults have been released at 150 different locations in twelve counties. *Oxyops vitiosa* larvae are flush feeders, consuming the seasonal flush of newly developed, expanding leaves at branch tips. Larval feeding results in tip dieback, defoliation and reduced flowering. In recent studies, for instance, an 80-percent reduction in flowering was observed among damaged melaleuca trees as compared to a similar undamaged group. The melaleuca snout beetle are the first of a suite of insects that is being studied for release.

The second melaleuca biocontrol agent was released from quarantine in February 2002. Approximately 350,000 psyllids (*Boreioglycaspis melaleucae*) have now been released, and the agent has established at 23 sites in south Florida. Populations are building quickly and have spread as much as 20 miles from release points. Nymphs suck the plant juices and inject phytotoxic saliva that kills the tissue surrounding the feeding site. Although only a short time has elapsed since the release of the insect, preliminary data have shown that psyllid attack results in 60-percent mortality among seedlings after a single year of introduction. Entomologists analyzing the problem estimate that four to five insect species will be required to effectively suppress melaleuca's invasive capacities.

In Fiscal Year 2002 (FY2002), the District was awarded a five-year interagency cooperative grant from the U.S. Department of Agriculture - Agricultural Research Service (USDA-ARS). This cooperative grant was for the Areawide Management Evaluation of Melaleuca project (TAME Melaleuca). TAME Melaleuca is an interagency demonstration and implementation project funded by the USDA-ARS. The goal of this project is to assess and demonstrate ecologically based, integrated melaleuca management strategies for landowners and land managers. This is the second areawide grant in the country that has been awarded for an invasive plant.

The TAME Melaleuca team has selected six demonstration sites and is distributing limited funds to selected locations to develop demonstration sites. Project leaders are working with land managers from each demonstration site to develop site-specific integrated melaleuca management plans. An annual budget of $35,000 per site is available to private and public landowners to defray management cost increases that may arise due to participation in the TAME Melaleuca project. This is a unique opportunity for interested land managers – both public and private – to receive financial and technical support for using integrated melaleuca management tactics that they otherwise might consider too complicated, costly, or risky.

As part of TAME Melaleuca, the District has been charged with completing an assessment of the distribution of melaleuca outside of its native range and coordinating the operational work on all of the field demonstration sites.

During FY2003, the District treated approximately 4,436 acres of melaleuca using ground application of herbicides and 10,177 acres using aerial application of herbicides. These treatments of melaleuca took place in all of the WCAs, the Pennsuco Regional Offsite Mitigation Area and along Krome Avenue in Miami-Dade County, Cell 17/18 in Broward County, the East Coast Buffer Strip, Shingle Creek, and Lake Okeechobee. On non-District properties, with funds provided by the FDEP, control took place in the Everglades National Park (various locations), J.W. Corbett Wildlife Management Area, Hungryland Slough, Key Largo Dove Creek Park, Estero Bay, Hurricane Bay, Arthur R. Marshall Loxahatchee National Wildlife Refuge, Port Charlotte, and Loxahatchee Slough in Palm Beach County.

Through regional control efforts, steady progress has been made. Today, large untreated monocultures of melaleuca are limited to the Arthur R. Marshall Loxahatchee National Wildlife Refuge, WCA-2B, East Everglades Acquisition Area, the Everglades buffer strip, and wetlands in Miami-Dade, Broward, and Lee counties. Control efforts by local, state, and federal land management agencies have resulted in a decrease in melaleuca acres.

OLD WORLD CLIMBING FERN (*Lygodium microphyllum*)

There are two species of exotic climbing fern naturalized in Florida. Old World climbing fern (*Lygodium mircophyllum*) is native to wet tropical and subtropical regions of Asia, Africa, and Australia. It has become a serious threat to South Florida natural areas, especially the Everglades, where it is increasing in density and range. Japanese climbing fern (*L. japonicum*) is native to temperate and tropical Asia. It occurs from eastern Texas through the southern states to North Carolina and Northern Florida. Japanese climbing fern has not yet been found in the Everglades. Old World climbing fern has reached a critical mass in South Florida such that new populations, presumably from windborne spores, are constantly being reported by natural resource managers and private landowners throughout the southern peninsula.

Old World climbing fern invades many freshwater and moist habitats in Florida. It is common in cypress swamps, pine flatwoods, wet prairies, sawgrass marshes, mangrove communities, and Everglades tree islands (Jewell, 1996; Pemberton and Ferriter, 1998). This plant seriously alters fire ecology, which is important to maintaining Florida habitats. Prescribed burns and wildfires that normally stop at the margins of flooded cypress sloughs will burn through areas infested with this fern. Burning mats of this lightweight fern break free during fires and are kited away by heat plumes, leading to distant fire-spotting. Additionally, the plant acts as a flame ladder, carrying fire high into native tree canopies. Under natural conditions, fire rarely enters the tree canopy. Canopy fires are deadly to native cypress forests and pine flatwoods. Old World climbing fern has caused the loss of some canopy trees with such crown fires, as well as a loss of native epiphytes and bromeliads residing on tree trunks (Roberts, 1996).

Old World climbing fern forms dense mats of rachis plant material. These thick, spongy mats are slow to decompose, exclude native understory plants, and they can act as a site for additional fern colonization. It is difficult for other plant species to grow through the dense mat made by this fern, thereby reducing plant diversity. Large expanses of fern material also may alter drainage and water movement.

Wiry Old World climbing fern rhizomes are able to accumulate into dense mats one or more meters thick above native soil. Vegetative growth and production of fertile pinnules continues throughout the year. Spores can germinate in 6 to 7 days, and 5-month-old spores retain an 80-percent germination rate (Brown, 1984). Fertile pinnules are usually produced where plants receive sunlight. Such exposed locations also aid wind-borne dispersal of the spores. Old World climbing fern often establishes first at pineland/wetland ecotones. It is usually killed back by fire but not eliminated, and regrowth is common (Maithani et al., 1986).

The center of dispersal in Florida is reported by Beckner (1968) and by Nauman and Austin (1978) as the Loxahatchee River basin in southern Martin and northern Palm Beach counties. By 1993, the fern expanded into western Martin County and central Palm Beach County. It is now spreading rapidly throughout the southern part of the state. Results from the 1993 District regional survey showed that Old World climbing fern occupied an estimated 10,935 hectares in South Florida. By 1997, this number had climbed to 15,800 hectares (Pemberton and Ferriter, 1998), and by 1999, the species was present in more than 43,000 hectares.

The tree islands of the northern Everglades (WCA-1) are significantly impacted by Old World climbing fern. Large tree islands are completely blanketed with this plant. Recent reports indicate that the fern is spreading south through WCA-2 and WCA-3. A large infestation totaling approximately 1,000 acres was discovered in the western coastal areas of the ENP in 2000. By August 2003, this population expanded to cover more 10,000 acres of coastal scrub prairie (Tony Pernas, personal communication). Populations were also reported in Collier-Seminole State Park, Fakahatchee Strand State Preserve, Florida Panther National Wildlife Refuge and the Ten Thousand Islands National Wildlife Refuge, and on the boundary of Biscayne National Park. Big Cypress National Preserve populations are expanding in and are now found throughout northern portions of the preserve.

Increased hydroperiod does not seem to have an effect on this species, as it has expanded greatly in areas that have experienced several years of higher-than-normal water levels. This species is not restricted to elevated Everglades tree islands; it has been noted growing in open, flooded sawgrass marshes in the Arthur R. Marshall Loxahatchee National Wildlife Refuge (Jewell, 1996). Old World climbing fern threatens to dominate many native plant communities in South Florida and Central Florida within the next decade (Ferriter, 1999a).

The District has been actively involved in operational field research for *Lygodium* control since 1997. Current control options include preventative, herbicidal, biological, mechanical, and physical methods. The District conducted the first large-scale herbicide treatment of Lygodium in the Florida in January 1999 at the Corkscrew Regional Ecosystem Watershed (CREW) and the DuPuis Management Area. It is extremely important that the District, as well as other land managers, continue to identify and treat small populations of exotic climbing fern before they become substantial infestations. Early detection and treatment is crucial to successful and economical management of this plant. Land managers statewide agree that biological control holds the key to effective long-term regional management of this species; however, overseas searches and rigorous quarantine testing take many years.

Treatment of individual plants is the most conservative and effective approach in natural areas; however, locating, accessing and treating individual vines can be extremely time consuming. Aerial applications of herbicides at certain times of the year may, in some cases, reduce non-target damage. Wintertime aerial herbicide applications in deciduous cypress forests have been preliminarily successful in controlling the fern without significant damage to native species. Large-scale control on evergreen tree islands is extremely problematic and follow-up treatments are a logistical nightmare for field personnel. The USEPA granted Florida governmental agencies a Special Local Needs (SLN) label for the use of ESCORT® (Metsulfuron methyl) herbicide in dry wetlands in FY2003. It is hoped that this herbicide will provide selective control of *Lygodium* in native plant communities and reduce non-target damage.

The District has been funding biological control investigations and research with the USDA-ARS since 1997. A petition for release is complete and approved for one biocontrol agent, a moth (*Cataclysta camptozonale*), and plans for release are underway.

BRAZILIAN PEPPER (*Schinus terebinthifolius*)

Brazilian pepper was imported as an ornamental in the 1840s (Barkley, 1944). It has bright red fruits and shiny green leaves that increased its popularity as a substitute for holly in Florida, quickly earning the misnomer Florida holly (Morton, 1971a). Its fruits are commonly consumed by frugivorous birds. The dispersal of seeds by these birds – namely, mockingbirds, cedar waxwings, and especially migrating robins – has been responsible for the spread of this species

into outlying, non-Brazilian pepper-dominated ecosystems, especially those that include perches, such as trees and utility lines (Ewel et al., 1982). Raccoons and opossums are known to ingest the fruits, with the animals' stools providing additional nutrients for seed germination and seedling growth.

Brazilian pepper has invaded a variety of areas, including but not limited to fallow farmland, pinelands, hardwood hammocks, roadsides, and mangrove forests. It is found in areas with a high degree of disturbance as well as in natural areas with little disturbance (Woodall, 1982; Ferriter, 1997). Brazilian pepper forms dense thickets of tangled woody stems that completely shade out and displace native vegetation. It has displaced some populations of rare, listed species such as the beach jacquemontia (*Jacquemontia reclinata* – House, U.S., and Florida. Endangered), and beach star (*Remirea maritima Aubl*., Florida Endangered).

Brazilian pepper sprouts easily from the trunk and roots, even if the plant is undamaged. It flowers in every month of the year in Florida, with the most intense period of flowering in the fall. Brazilian pepper fruits profusely in South and Central Florida, with wildlife consumption of fruits contributing in large part to the spread of seeds (Ewel et al., 1982). It produces chemicals in leaves, flowers, and fruits, and these chemicals can irritate human skin and respiratory passages (Morton, 1978; Ewel et al., 1982).

Brazilian pepper is naturalized in most tropical and subtropical regions, including Brazil and other South American countries, parts of Central America, Bermuda, the Bahamas, the West Indies, Guam, Mediterranean Europe, North Africa, southern Asia, and South Africa. In the United States it occurs in Hawaii, California, southern Arizona, and Florida (as far north as Levy and St. Johns counties and as far west as Santa Rosa County) (EPPC, 1996).

Brazilian pepper does not become established in deeper wetland communities, and it rarely grows on sites inundated longer than three to six months. In the Park, for example, it is absent from marshes and prairies with hydroperiods exceeding six months, as well as from tree islands with closed canopies (LaRosa et al., 1992). However, Brazilian pepper can tolerate extended periods of shallow-water inundation once established. It is unclear what effects deepwater flooding has on established Brazilian pepper populations.

Concern over the occurrence of Brazilian pepper in salt-tolerant plant communities (e.g., mangrove forests in southern Florida, especially in the Park) led Mytinger and Williamson (1987) to investigate its tolerance to saline conditions. Seed germination and transplanted seedlings did not succeed at salinities of 5 parts per thousand (ppt) or greater, which would largely exclude it from becoming established in mangrove forests. However, invasion of saline communities can occur if salinity declines due to changes in drainage patterns resulting from natural phenomena or human activities.

Within the Everglades, Brazilian pepper has invaded most of the canal levees and much of the power line rights-of-way. Some of the tree islands of WCA-1 have been colonized to varying degrees by this species. By far, the greatest areal coverage of Brazilian pepper within the EPA is an area called the Hole-in-the-Doughnut (HID). Situated within the boundaries of the Everglades National Park, the HID comprises approximately 4,000 hectares of previously farmed lands (farming ceased in 1975). More than 40 percent (1,600-plus hectares) of this area has been invaded by a dense forest of Brazilian pepper. This species also has infested more than 40,000 hectares in the isolated Ten Thousand Islands and is widely scattered throughout the Park, occurring in all habitats, particularly disturbed areas. Brazilian pepper is now estimated to occupy more than 400,000 ha in Central and South Florida (Ferriter, 1997; Wunderlin et al., 2000).

Park scientists have researched a number of restoration techniques over the years. Only the complete removal of the disturbed substrate has resulted in recolonization by native vegetation to the exclusion of Brazilian pepper. The Park initiated a full-scale substrate removal project for the entire HID in 1996. To date, 8 percent of the Brazilian pepper forest has been restored. This project is funded through 2016.

Along canal levees, highways, and power line rights-of-way, most control work involves the selected use of herbicides or the use of heavy equipment to physically remove Brazilian pepper, followed by a herbicide application. Large single trees are usually treated with a basal bark herbicide application. This treatment provides for the greatest selectivity, with no non-target effects. In dense stands, foliar herbicides may be used and are most effective when applied aerially.

Biological controls have not yet been approved for general release against Brazilian pepper, although District-sponsored research is ongoing. The University of Florida's Department of Entomology and Nematology has been investigating insect vectors of Brazilian pepper since 1994. From exploratory surveys conducted in Brazil, several insects have been identified as potential biological control agents. Three insect species – a thrips (*Pseudophilothrips ichini*), a sawfly (*Heteroperreyia hubrichi*), and a leaf roller (*Episimus utilis*) – have been selected for further study (Cuda et al., 1999). Host-specificity testing for the sawfly is completed, and a petition to release this species has been submitted.

AUSTRALIAN PINE (*Casuarina equisetifolia, Casuarina glauca*)

Australian pine was introduced to Florida in the late 1800s (Morton, 1980). It naturalized since the early 1900s along coastal dunes (Small, 1927). Australian pine was planted extensively in the southern half of the state as windbreaks and shade trees (Morton, 1980). It is salt tolerant and seeds freely throughout the area, growing even in front-line dunes (Watkins, 1970; Long and Lakela, 1971). Its rapid growth, dense shade, dense litter accumulation, and other competitive advantages are extremely destructive to native vegetation (Nelson, 1994). Australian pine can encourage beach erosion by displacing deep-rooted native vegetation, and it can interfere with the nesting of endangered sea turtles and the American crocodile (Klukas, 1969).

Three species of Australian pine trees invade Florida's wild lands. Since the introduction of the trees in the late 1800s, they have been widely planted throughout the southern peninsula. It was not until 1992 that the state banned the further propagation and sale of these trees as ornamentals. Australian pine grows very fast (1 to 3 meters per year); is salt tolerant; readily colonizes rocky coasts, dunes, sandbars, and islands; and invades far-inland, moist habitats such as the East Everglades Area (EAA) of the Everglades National Park (Morton, 1980). It forms dense forests, crowding out all other plant species. It has crowded out vast areas of natural vegetation along Florida's coastline, where the public vehemently opposes any removal efforts.

Australian pine is not freeze tolerant and is sensitive to fire (Morton, 1980). It loses branches easily and topples in high winds (Morton, 1980). Australian pine produces allelopathic compounds that inhibit growth of other vegetation (Morton, 1980), and it can colonize nutrient-poor soils easily by nitrogen-fixing microbial associations (Wilson, 1997). It reproduces prolifically by seed – as many as 600,000 to the kilogram – with seeds dispersed by birds (especially exotic parrots and parakeets), water, and wind (Morton, 1980). The fruiting heads of this species float (Maxwell, 1984).

Australian pine occurs throughout South Florida, from Orlando south, on sandy shores and in pinelands. It occurs as far north as Dixie County on the west coast and Volusia County on the east (Wunderlin et al., 1995). It frequently colonizes disturbed sites such as filled wetlands, road shoulders, cleared land, and undeveloped lots (Maxwell, 1984).

Australian pine is mainly a problem along levee berms in the WCAs. A large portion of the east Everglades and the southern saline glades (C-111 basin), as well as coastal areas of the Park, are heavily impacted. The seeds are windblown, carried by birds, and probably moved throughout the EPA via water flow in canals. Australian pine has a microbial association with nitrogen-fixing organisms, and this allows it to colonize and grow prolifically in nutrient-impoverished soils. With this nitrogen-fixing capacity and a lack of natural enemies, Australian pine has a tremendous competitive edge over natural vegetation. Until recently, Australian pine was the dominant tree species growing along the canal levees of the EPA. The largest remaining populations of Australian pine in the EPA are original plantings growing along S.R. 27 in Broward County and wild populations growing in the EAA.

Fire is sometimes effective in dense stands with sufficient fuel (tinder) on the ground. Larger trees usually resprout from the bases and require some form of follow-up herbicide treatment. There is no biological control research being conducted at this time, even though Australian pine is a good candidate for this control method. It is not likely that biological control will be an option in the near future due to the tree's popularity in urban landscapes and coastal communities.

The primary method of control is selective use of herbicides. Although several soil-active herbicides are effective, the most common control techniques involve basal bark and cut-stump herbicide applications. The District has nearly completed its control of mature Australian pine trees growing along canal levees of the EPA and in District-managed lands in the southern Everglades. Periodic follow-up is required to treat seedlings that arise from the residual seed bank. Retreatment is conducted prior to saplings maturing and flowering in order to deplete the existing seed bank.

LATHERLEAF (*Colubrina asiatica*)

Latherleaf is thought to have been brought to Jamaica by east Asian immigrants in the 1850s for traditional use as medicine, food, fish poison, and soap substitute (Burkill, 1935; Perry, 1980). It is noted as naturalized in the Keys and Everglades by Small, 1933 and as aggressively spreading along these coasts by (Morton, 1976; Austin, 1978). Latherleaf invades marly coastal ridges just above the mean high-tide line (Russell et al., 1982), tropical hammocks, buttonwood and mangrove forests, and tidal marshes (Schultz, 1992). It also forms thickets on disturbed coastal roadsides. Latherleaf can invade disturbed and undisturbed forest sites (Olmsted et al., 1981; Jones, 1996), forming thick mats of entangled stems up to several feet deep, and growing over and shading out native vegetation, including trees (Langeland, 1990; Jones, 1996). This species is of particular concern in Florida's coastal hammocks, where it threatens a number of rare, listed native plant species such as mahogany, thatch palm, wild cinnamon, manchineel, cacti, bromeliads, and orchids (Jones, 1996). It is also now in every park in the Florida Keys, where it threatens rare natives such as bay cedar and beach star.

Latherleaf requires considerable light, with seedling growth rate increasing where shade is removed; stems may grow 10 meters in a single year (Schultz, 1992). It forms adventitious roots where branches touch the ground, and it vigorously resprouts from cut or injured stems. This species may reach seed-producing maturity within a year (Russell et al., 1982; Schultz, 1992). It flowers in Florida most often in July, with fruits maturing in September (Jones, 1996), but it is

reported as flowering year-round (Long and Lakela, 1971; Wunderlin, 1982). Loose soil is usually required for germination, with seeds able to retain viability in soil for at least several years (Russell et al., 1982). Long-distance dispersal is aided primarily by storms and extreme tides, which allow ocean currents to carry away the buoyant, salt-tolerant fruits and seeds (Carlquist, 1966).

Latherleaf is found naturally from eastern Africa to India, southeast Asia, tropical Australia, and the Pacific Islands, including Hawaii, where it typically occurs as scattered plants on sandy and rock seashores (Brizicky, 1964; Johnston, 1971; Tomlinson, 1980). From Jamaica it has spread in the New World to other Caribbean islands, Mexico, and Florida with the aid of ocean currents and storm tides (Russell et al., 1982). In Florida, it is now naturalized in coastal areas from Key West north to Hutchinson Island in St. Lucie County (Schultz, 1992).

Nowhere in Florida are the ecological effects of latherleaf more noticeable than in the Everglades National Park (Jones, 1997). Latherleaf is well distributed throughout the Park's coastal areas. It occurs from the Ten Thousand Islands south to Cape Sable along the Gulf Coast and east along the northern fringe of Florida Bay to the Florida Keys. Latherleaf occupies approximately 500 hectares of the most remote areas of the Park. Coastal hardwood forests are among the most threatened plant communities in southern Florida. The aggressive colonization nature of latherleaf and continued expansion into these areas is especially disconcerting. Fortunately, there is no evidence of long-distance dispersal mechanisms on land that could further facilitate its spread inland. Storms and extreme tides appear to be the only dispersal agents.

Latherleaf was casually noted as existing in the Park until the 1970s, when large monotypic stands up to one hectare in area were observed along the coast of Florida Bay (Russell et al., 1982). In 1974, Park staff reported 130 hectares of latherleaf growing at sites along the coast from Christian Point to Santini Bight, including some of the offshore keys. In 1980, a detailed vegetation and mapping study of the coast between Flamingo Bay and Joe Bay revealed 50 hectares of high-density stands (Olmsted et al., 1981). Interpretation of 1987 color infrared aerial photographs (1:10,000 scale) of the Park by Rose and Doren (1988) showed that the areal extent of medium- to high-density latherleaf along the same stretch of coastline (Snake Bight to Joe Bay) was 230 hectares. Photo interpretation of 1994–1995 U.S. Geological Survey National Aerial Photography Program (USGS-NAPP) color infrared photographs (1:40,000 scale) by the University of Georgia's Center for Remote Sensing and Mapping Science has provided the latest information on the distribution of latherleaf in the Park. Low- to high-density infestations of latherleaf covered nearly 420 ha for the same area. An 84-percent increase in latherleaf extent over the seven-year period was reported. From this mapping data, it can be estimated that the areal extent of latherleaf may double every 10 years, spreading at the rate of approximately 25 hectares per year.

Latherleaf has been successfully managed in Biscayne National Park as well as on other public lands. Uprooting the young, shallow-rooted plants, cutting scandent stems, and applying herbicides (either cut-stump or basal bark) have proven effective (Langeland, 1990). Biological control is not currently available – a situation that is not likely to change anytime soon. To date, management efforts within the Park have been restricted due to funding limitations.

WATER HYACINTH (*Eichhornia crassipes*)

Water hyacinth is reported as a weed in 56 countries (Holm et al., 1979). It was introduced to the United States in 1884 at an exposition in New Orleans, reaching Florida in 1890 (Gopal and Sharma, 1981). By the late 1950s, water hyacinth occupied about 51,000 hectares of Florida's

waterways (Schmitz et al., 1993). It grows at explosive rates, exceeding any other tested vascular plant (Wolverton and McDonald, 1979), doubling its populations in as little as 6 to 18 days (Mitchell, 1976). In large mats it degrades water quality and dramatically alters native plant and animal communities (Gowanloch, 1944; Penfound and Earle, 1948). Large mats of water hyacinth can collect around water control structures and impede flow.

Water hyacinth reproduces both vegetatively and sexually (Penfound and Earle, 1948; Gopal and Sharma, 1981). It quickly forms new rosettes on floating stolons; with stolons easily broken, the plants and mats are transported by wind and water. Leaves are killed back by moderate freezes, but they quickly regrow from the stem tip protected beneath the water surface. It flowers year-round in mild climates, producing abundant seeds in developed mats (Penfound and Earle, 1948). Numerous seedlings are seen in conjunction with lake drawdowns.

Water hyacinth now occurs globally in the tropics and subtropics and also further north and south where it can escape severe cold (Holm et al., 1977). It is found throughout Florida, north to Virginia (and New York) and west to California and Hawaii – 16 states in all (USDA, 1997). Under ideal growing conditions these plants can increase their surface coverage by 25 percent per month when not managed (Langeland, 1988). The thick, floating mats of vegetation block boating access within the EPA, clog water control structures, negatively impact water quality, and reduce native plant species. These plants are almost exclusively located in artificial environments. They are common in all canals and around most of the water control structures. In addition, water hyacinth can often be found growing at the mouth of airboat trails that transect the canals. However, the plants do not appear to compete with native vegetation in the EPA away from these disturbed environments.

Water hyacinth and water lettuce both are free-floating aquatic plants. They cause similar problems and are managed in a like manner. Consequently, control methods for both species will be discussed together. The District conducts operations under permit from the FDEP and performs all work in accordance with both federal and state regulations. The District's primary goal is to implement a "maintenance control program." Chapter 372.925, F.S. defines maintenance control as "…a method of managing exotic aquatic plants in which control techniques are utilized in a coordinated manner on a continuous basis to maintain a plant population at the lowest feasible level." Maintenance control results in the use of fewer herbicides, the deposition of less organic matter (from dead leaves and plants), less overall environmental impact by weeds, and reduced management costs.

The primary method of floating exotic aquatic weed control for the Everglades Protection Area has been with herbicides. The herbicides used for management of these plants are diquat and 2,4-D. Both are fully approved by the USEPA for application to aquatic sites. Mechanical controls have been generally limited to work in and around structures where plants have modified discharge capacities and need to be physically removed. The process of mechanically harvesting water hyacinth and water lettuce is slow and expensive (costing 10 to 15 times more than herbicide controls). Harvested plant biomass must be removed from the water to be effective, and near-shore disposal options are often limited, adding considerable costs to mechanical removal.

Mechanical harvesting cannot be considered a stand-alone option for floating weed management in the EPA canals. While insects have been introduced as biological controls for both species, they have not yet introduced the compliment of insect vectors to "control" plant growth. USDA-ARS biocontrol researchers have recently completed field assessments in Peru searching for and identifying candidate insects for study in U.S. quarantine. Herbicides applications remain the primary control method and are applied either by boat or helicopter.

WATER LETTUCE (*Pistia stratiotes*)

Water lettuce may have been introduced to North America by natural means or by humans (Stoddard, 1989). It was seen as early as 1774 by William Bartram in "vast quantities" several miles in length and in some places a quarter of a mile in breadth in the St. Johns River (Van Doren, 1928). It has been suggested that trade via St. Augustine, founded in 1565, may have provided an early avenue for introduction into the St. Johns watershed (Stuckey and Les, 1984). Water lettuce is capable of forming vast mats that disrupt submersed plant and animal communities. These mats can collect around water control structures and interfere with water movement and navigation (Attionu, 1976; Holm et al., 1977; Bruner, 1982; Sharma, 1984). It is considered a serious weed in Ceylon, Ghana, Indonesia, and Thailand and is at least present as a weed in 40 other countries (Holm et al., 1979).

Water lettuce reproduces rapidly by vegetative offshoots formed on short, brittle stolons. Rosette density varies seasonally, from less than 100 to more than 1,000 per square meter in South Florida (Dewald and Lounibos, 1990). Seed production, once thought not to occur in North America, is now considered important to reproduction and dispersal (Dray and Center, 1989). Water lettuce is not cold tolerant (Holm et al., 1977). It can survive for extended periods of time on moist muck, sandbars, and banks (Holm et al., 1977).

Water lettuce is now one of the most widely distributed hydrophytes in the tropics (Holm et al., 1977). In North America, it occurs in peninsular Florida and locally westward to Texas (Godfrey and Wooten, 1979). It is also found persisting in coastal South Carolina (Nelson, 1993). Water lettuce occurred in 68 public water bodies in Florida by 1982 and in 128 water bodies by 1989 (Schardt and Schmitz, 1991). In the Everglades region, water lettuce is mainly restricted to canals and around water control structures. It also occurs in the artificial water bodies of the Park.

TORPEDOGRASS (*Panicum repens*)

For the last several decades, the District and FDEP have tracked the expansion of torpedograss in Lake Okeechobee from its first reports of several hundred acres by FDEP in the early 1980s to 16,000 acres reported on the SFWMD's 1996 digital vegetation map. Since publication of this map, it is estimated the plant has continued its expansion in the lake to cover at least 18,000 acres.

According to the SFWMD's five-year torpedograss management plan for Lake Okeechobee, initial control efforts will aim to limit the plant's further expansion into new areas of the lake. After establishing boundaries from expansion fronts, management will proceed in areas already densely overtaken by the grass. In FY2003, approximately 2,500 acres of torpedograss management took place in the 100,000-acre marsh on the west side of Lake Okeechobee via aerial herbicide application.

Imazapyr and glyphosate herbicides are used in combination to treat torpedograss in Lake Okeechobee. To date, trials of various herbicides have found this to be the best available management practice. Cooperative plans are underway with the FDEP and the University of Florida to evaluate the effects of native fungal inoculation to control torpedograss in the lake and varying control results due to variations in environmental conditions including soil moisture. Different herbicides, or combinations of herbicides, may control torpedograss effectively and cause less damage to native plants. Research continues aiming to find treatments, which could possibly be less costly, more effective, or more selective.

LOBATE LAC SCALE (*Paratachardina lobata lobata*)

The Lobate lac is a scale insect that is native to India and Sri Lanka. In 1999, it was first spotted on hibiscus (*Hibiscus rosa-sinensis*) in Davie, Florida. The scale began spreading at an alarming rate with new populations being reported with increasing frequency throughout South Florida. Preliminary results from ongoing Cooperative Agricultural Pest Survey (CAPS) work indicates that the pest has infested plants in Broward, Collier, Miami-Dade, Palm Beach, and Hendry counties. Woody plants seem to be the hardest hit, with native and exotic plant species both heavily impacted however it impacts over 150 plants in 50 families.

MEXICAN BROMELIAD WEEVIL (*Metamasius callizona*)

Florida has 16 species of native bromeliads, many of which are restricted to the southern portion of the state. Florida is at risk of losing some of these unique plants as an invasive exotic weevil is destroying populations these native bromeliad species at an alarming rate. The Mexican bromeliad weevil (*Metamasius callizona*) entered Florida in a shipment of bromeliads from Mexico, and by the time it was discovered in a nursery in 1989, it had already become established in Broward County. It is now found in 16 counties in south Florida and is fast-approaching the state's most rare, endangered bromeliad populations in the Everglades. The weevil has been found as far north as Polk and Brevard counties.

In November and December 2002, a survey was performed to document the presence or absence of the Mexican bromeliad weevil on six SFWMD owned properties; Chandler Slough, Lake Marion Creek, CREW, Fisheating Creek, DuPuis Reserve, and Pal-Mar. Of these properties, the presence of the weevil was documented at several locations in Fisheating Creek, DuPuis Reserve and Pal-Mar. In the spring 2003, the SFWMD collected seeds on DuPuis, PalMar, and CREW for germination by Florida Department of Agriculture and Consumer Service, Division of Plant Industry (FDACS-DPI) registered nursery growers. After the weevil is no longer considered a threat to the bromeliads, the resulting seedlings will be returned to the sites where they were collected.

OTHER SPECIES OF CONCERN IN SOUTH FLORIDA

Other exotic species of concern in South Florida include Java plum (*Syzygium cumini*), earleaf acacia, (*Acacia auriculforms*), ficus (*Ficus microcarpa*), bishopwood (*Bischofia javanica*), guava (*Psidium guajava*), Surinam cherry (*Eugenia uniflora*), lead tree (*Leucaena leucocephala*), climbing cassia (*Senna pendula*), wild taro (*Colocasia esculenta*), lantana (*Lantana camara*), Burma reed (*Neyraudia reynaudiana*), napiergrass (*Pennisetum purpureum*), kudzu (*Pueraria montana*), and schefflera (*Schefflera actinophylla*).

Shoebutton ardisia (*Ardisia elliptica***)** is a shade-loving shrub that was originally reported from the Hole-in-the-Doughnut. It has spread into adjacent tropical hardwood hammocks in the Long Pine Key area of the Park (Seavey and Seavey, 1994) and was observed to have spread to the Flamingo Bay area in 1995 (Doren and Jones, 1997). Other species of concern in the Park are less widespread and extremely variable in their distributions, the habitats they invade, and the sizes of their infestations. Several of these species have persisted from cultivation and have shown the ability to spread from their points of introduction: sisal hemp (*Agave sisalana*), woman's tongue (*Albizia lebbeck*), orchid tree (*Bauhinia variegata*), mast wood (*Calophyllum antillanum*), Surinam cherry, lantana, lead tree, tuberous sword fern (*Nephrolepis cordifolia*), half

flower (*Scaevola taccada*), ground orchid (*Oeceoclades maculata*), guava, oyster plant (*Rhoeo spathacea*), bowstring hemp (*Sansevieria hyacinthoides*), shefflera, arrowhead vine (*Syngonium podophyllum*), and tropical almond (*Terminalia catappa*). Infestations consist of scattered individuals, except in the case of sisal hemp, tuberous sword fern, ground orchid, oyster plant, bowstring hemp, and arrowhead vine – all species that spread vegetatively and produce locally dense populations. The coastal species, mahoe (*Hibiscus tiliaceus*) and seaside mahoe (*Thespesia populnea*), and the grasses, cogongrass (*Imperata cylindrica*), Burma reed, and napiergrass, have reached the Park by natural expansion from outside sources and are represented by single plants and dense clones.

Nonnative animal species of concern include insects, marine and freshwater fish, invertebrates, reptiles, amphibians, mammals, and birds. Due to the complexity of assessing the distribution and impacts of these varied taxa, biologists are now only beginning to prioritize species of concern in South Florida. This work is ongoing and will be coordinated through the Florida Invasive Animal Task Team (FIATT). In addition to Lobate lac scale and the Mexican bromeliad weevil, species generally held to be of the greatest concern include the feral pig (*Sus scrofa*), Norway and black rats (*Rattus norvegicus* and *R. rattus*), nine-banded armadillo (*Dasypus novemcinctus*), European starling (*Sturnus vulgaris*), brown caiman (*Caiman crocodilus*), Tokay gecko (*Gecko gecko*), spinytail iguana (*Ctenosaura pectinata, C. similis*), Cuban knight anole (*Anolis equestis*), brown anole (*A. sagrei*), boa constrictor (*Boa constrictor*), Burmese python (*Python molurus*), Cuban treefrog (*Osteopilus septentrionalis*), Asian swamp eel (*Monopterus albus*), diaprepes weevil (*Diaprepes abbreviatus*), brown citrus aphid (*Toxopotera citricida*), red fire ant (*Solenopsis invicta*), Pacific whiteleg shrimp (*Liptopinaeus vannamei*), zebra mussel (*Dresseina polymorpha*), red-rimmed melania aquatic snail (*Melanoides tuberculata*), and banded tree snail (*Orthalicus floridensis*).

INFORMATION GAPS AND FUTURE NEEDS

The elements of a comprehensive invasive exotic plant management strategy – legislation, coordination, planning, research, education, training, and resource input – have been in place in Florida for many years. The plants identified above are all being controlled to some extent by most state or federal agencies. Unfortunately there are dozens of other exotic species in the Everglades with unknown distributions and invasive potentials. The threat of exotic invasive animals is recognized but is not being addressed by any agency. Funding and coordination for a comparable nonindigenous animal management program are badly needed. Little can be done without a committed effort to develop ecological understanding of the spread, effects, and behaviors of exotic animals in the Everglades.

Regardless of taxa, the invasiveness of a species is often somewhat slow to develop. Species that appear benign for many years or even decades can suddenly spread rapidly following certain events, such as flood, fire, drought, long-term commercial availability, or some other factor. There is a need to recognize these species during their incipient phase or prior to introduction to maximize available management resources.

RESEARCH NEEDS

It is tempting to assume that when restoration goals are achieved, results will include a reduced need to control exotic species. Although it is true that the spread of some exotic species can be reduced by increasing hydroperiods (e.g., Brazilian pepper), there has been little or no research to determine what effects long-range hydrologic changes or nutrient reductions will have

on most of the other exotic species throughout the system. Nutrient enrichment studies have looked at changes to native flora but have excluded study of exotics. Old World climbing fern, melaleuca, and Brazilian pepper have successfully invaded those areas with the least apparent human alterations, including the mangrove zones of Southwest Florida and remote areas of Big Cypress National Preserve. Exotic plant communities in the Everglades Stormwater Treatment Areas (STAs) will need to be monitored and measured as changes to the hydrology are made. A more comprehensive approach needs to be taken when looking at the long-term restoration process with regard to the exotic species composition response. It is necessary to educate the public and policy makers that invasive exotic species will always require some level of maintenance and that new introductions will need to be stopped in order to avoid future costs.

Also, as previously mentioned, management of invasive animals remains a nascent field of study in the region, with little or no published material available to guide planners and resource managers.

MANAGEMENT EFFORTS

Economic impacts of invasive species cannot be directly drawn from the literature. Studies documenting the expansion of some species imply that control would be cheaper when populations are small (Laroche and Ferriter, 1992). However, no direct analyses of the environmental and cultural costs and benefits of invasive plant control in South Florida are available in the literature. The lack of such background information limits the strength of arguments supporting control of these pest species. Further, it might be argued that there should be no need to study such obvious catastrophes. Yet, basic foundational research is often needed to construct convincing arguments. A few citations do quantify the costs, impacts, and benefits resulting from control of aquatic weeds in a few Florida water bodies (Milon, et al., 1986; Colle et al., 1987), but none exist for wetlands such as the Everglades.

For many of the upland exotic plants, research has focused on the most effective and current control methods. Specific controls for melaleuca, Brazilian pepper, and a very few others have been the subject of both formal and informal research. For the majority of other species, only general guidelines of herbicide use or mechanical controls apply. A wide range of unknowns remains for each species. Additional research might show, for example, how best to control each plant in different settings, how to minimize nontarget damage, or whether treatments during different seasons or stages of growth of each plant will affect results. Virtually no research has been conducted to establish Best Management Practices (BMPs) for controlling exotic animal taxa. This work will be essential in developing integrated management plans for these species.

ECOLOGICAL IMPACTS OF INVASIVE SPECIES

Relatively little work has been done investigating the ecological impacts of invasive species in South Florida. While it is easy to visually observe the density of an invasive exotic plant in a natural area, the question of the effect of that density on wildlife has not been extensively studied. Without specific published proof, resource managers can be somewhat “out on a limb” when arguing for support to manage invasive species in the context of protecting ecological integrity of natural areas. Little research has been done to look at the effect of invasive species on nesting, denning, roosting, feeding, and foraging of indigenous wildlife.

Melaleuca (Ostrenko and Mazzotti, 1981; Sowder and Woodall, 1985; O’Hare et al., 1997) and Brazilian pepper (Gogue, 1974; Curnutt, 1989) have been found to decrease wildlife species

diversity. However, such studies are rare in the published literature. More publications have come from management, monitoring, or botanical investigations (Ferriter, 1997; Laroche, 1999). For most of the other invasive plants found in South Florida, very few publications are available of even a general nature, and of these, virtually none formally assess ecological impacts of each species.

COORDINATION EFFORTS

There is a clear need for a comprehensive plan that incorporates broad and consistent strategies, reduces agency inconsistencies, and takes into account differing agency mandates to achieve the goal of controlling all taxa of invasive species. This would result in a strategy that is appropriate for, applicable to, and coordinated with state and federal efforts to manage invasive species, both plants and animals, and which supports each agency in carrying out its role(s) in the broader program of invasive species control.

MANAGEMENT AUTHORITIES AND REGULATIONS

Although federal regulations on the importation of exotic species in general are extensive, there is virtually no regulation against bringing many exotic plant species into the United States. Barring the primarily agricultural weeds on the federal noxious weed list, importation laws focus on plant pests, not pest plants. Insects and pathogens are screened extensively at ports of entry, but plants are allowed to enter this country virtually unimpeded. Upfront screening methods need to be developed for new importation of exotic plant species. In Australia and New Zealand, there are strict regulations regarding exotic plant importation. These countries have developed comprehensive "white lists" of plants that are permitted for import. If a plant is not on the white list, then it cannot enter the country without a risk assessment being performed. At a minimum, state and federal agencies importing plants for food, fiber, or forage evaluation should have a protocol that screens for invasiveness prior to recommending new plant species for cultivation.

On the state level, the Department of Agriculture and Consumer Services Division of Plant Industry's assists in the control of invasive exotic plants in natural areas. However, in a regulatory context, plants on the FDACS noxious weed list are primarily listed because of their threat to agriculture, not to native ecosystems. While the FDACS' Division of Forestry fights a whole host of invasive exotic plants in its state forests, most of the plants being controlled are not included on its own agency's weed list.

In 1999, FDACS amended its list to include 11 new species that are threats to natural areas: carrotwood (*Cupaniopsis anacardioides*), dioscorea (*Dioscorea alata* and *D. bulbifera*), Japanese climbing fern, Old World climbing fern, Burma reed, sewer vine (*Paederia cruddasiana*), skunkvine (*P. foetida*), kudzu, downy myrtle (*Rhodomyrtus tomentosa*), and wetland nightshade (*Solanum tampicense*). The addition of these plants is a good indicator of a growing shift in agricultural rules and regulations to incorporate the protection of natural areas in their regulatory focus.

BETTER SUPPORT FOR BIOLOGICAL CONTROL

Isolating, testing, and releasing a host-specific insect to control an invasive exotic plant in the United States can take more than a decade, as in the case of the melaleuca snout beetle. After an insect has been properly selected and screened, it must be approved by a federal Technical Advisory Group (TAG) and a State Arthropod Committee in Florida. Although the process is

necessary, it can be extremely slow. There are no deadlines for review set by the committee(s), and the review process for each request for release does not seem to be a priority for staff at participating agencies, especially in the case of agents that target natural-area weeds. The process needs to be streamlined and formalized. The final federal authorization for biological release comes from the USDA's Animal and Plant Health Inspection Service. This approval process is often very slow.

After years of struggle, construction of two new quarantine facilities is nearly complete at a USDA site in Davie, Florida and a University of Florida site in Ft. Pierce, Florida. This is a positive step forward in light of the overwhelming need for additional biological control research.

DEVELOP PUBLIC/PRIVATE PARTNERSHIPS

Invasive exotic species recognize no political boundaries. Natural resource managers increasingly recognize that parochial management approaches to these problems are ineffective. Without a regional, integrated approach, effective containment is impossible. This strategy has proven successful with the management of melaleuca on public lands. However, adjacent privately held lands continue to harbor melaleuca. Without incentives for private landowners to remove melaleuca, these contaminated lands will be a seed source for neighboring public lands for years to come. It is hoped that the TAME Melaleuca project will serve as a model for other species-based control programs. Policy makers are beginning to acknowledge that comprehensive invasive species management may require the expenditure of public monies on private lands, or property tax breaks that provide a financial incentive for control.

LITERATURE CITED

Attionu, R.H. 1976. Some Effects of Water Lettuce (*Pistia stratiotes, L.*) on its Habitat. *Hydrobiologia*, 50: 245-254.

Austin, D.F. 1978. Exotic Plants and their Effects in Southeastern *Florida. Environ. Conserv*., 5: 25-34.

Barkley, F.A. 1944. Schinus L. *Brittonia*, 5: 160-198.

Beckner, J. 1968. *Lygodium microphyllum*, Another Fern Escaped in Florida. *Amer. Fern J*., 58: 93-94.

Bodle, M.J. 1993. Kudzu: King of the Forest, the Roadside, the Ditchbank and the Everglades. *Florida Water*, 1(2): 14-16.

Brizicky. 1964. The Genera of Anacardiaceae in the Southeastern United States. *J. Arn. Arb*., 43: 359-375.

Brown, V.M. 1984. A Biosystematic Study of the Fern Genus *Lygodium* in Eastern North America. M.S. Thesis, University of Central Florida, Orlando, FL.

Brunner, M.C. 1982. Water lettuce, *Pistia stratiotes, L. Aquatics*, 4: 4-14.

Burkill, I.H. 1935. *A Dictionary of the Economic Products of the Malay Peninsula*. Two Volumes. Crown Agents for the Colonies. London, England.

Carlquist, S. 1966. The Biota of Land-distanced Dispersal. III. Loss of Dispersibility in the Hawaiian Flora. *Brittonia*, 18 :310-35.

Carroll, J.D. 1994. An Integrated Plan for Ecosystem Restoration: Exotic Plants and Animals. Submitted to the Management/Operations Subgroup, April 1, 1994. U.S. Fish and Wildlife Service, Vero Beach, FL.

Colle, Douglas E. and J.V. Shireman. 1987. Influence of Hydrilla on Harvestable Sportfish Populations, Angler Use, and Angler Expenditure at Orange Lake, FL. *N. Amer. J. of Fish. Mgmt*., 7: 410-417.

Corn, M.L., E.H. Buck, J. Rawson and E. Fischer. 1999. Harmful Non-Native Species: Issues for Congress. CRS Report for Congress RL30123. Congressional Research Service, Washington D.C.

Cuda, J.P., J.C. Medal, D.H. Habeck, J.H. Pedrosa-Macedo and M. Vitorino. 1999. Classical Biological Control of Brazilian Peppertree in Florida. EN-820. University of Florida, Gainesville, FL.

Dewald, L.B. and L.P. Lounibos. 1990. Seasonal Growth of *Pistia stratiotes L.* in South Florida. *Aquatic Bot*., 36: 263-275.

Doren, R.F. and D.T. Jones. 1997. Plant Management in Everglades National Park. D. Simberloff, D.C. Schmitz and T.C. Brown, eds. pp. 275-286. In: *Strangers in Paradise*. Island Press, Washington, D.C.

Dray, F.A. Jr. and T.D. Center. 1989. Seed Production by *Pistia stratiotes L*. (water lettuce) in the United States. *Aquatic. Bot*., 33:155-160.

Duever, M.J., J.E. Carlson, J.F. Meeder, L.C. Duever, L.H. Gunderson, L.A. Riopelle, T.R. Alexander, R.L. Myers and D.P. Spangler. 1986. The Big Cypress National Preserve. Research Report. 8, National Audubon Society, New York, NY.

EPPC. 1996. Florida Exotic Pest Plant Council Occurrence Database. Unpublished. Data available by request via Website at http://www.fleppc.org/.

Ewel, J.J. 1986. Invasibility: Lessons from South Florida. pp. 214-230. Mooney, H.A. and J.A. Drake (eds.). In: *Ecology of Biological Invasions of North America and Hawaii*. Springer-Verlag, New York, NY.

Ewel, J.J., D.S. Ojima, D.A. Karl and W.F. DeBusk. 1982. Schinus in Successional Ecosystems of Everglades National Park. Report T-676. South Florida Research Center, Homestead, FL

Fairchild, D. 1947. *The World Grows Around My Door*. Scribner and Sons, New York. 347 pp.

Ferriter, A.P. (ed.). 1997. Brazilian Pepper Management Plan for Florida. Florida EPPC, West Palm Beach, FL. 38 pp.

Ferriter, A.P. 1999a. *Lygodium* Emergency Action Plan for Florida. A Report from Florida EPPC's Lygodium Task Force. Florida EPPC. 22 p.

Ferriter, A.P. 1999b. The Extent of Melaleuca Infestation in Florida. In Melaleuca Management Plan for Florida. Task Force Report. Florida Exotic Pest Plant Council, West Palm Beach, FL.

Florida Game and Fresh Water Fish Commission. 1999. Coordination Act Reports, Central and Southern Florida Comprehensive Review Study. FGFWFC, Tallahassee, FL.

Godfrey, R.K. and J.W. Wooten. 1979. *Aquatic and Wetland Plants of the Southeastern United States*. Monocots. University of Georgia Press, Athens, GA.

Goodyear, C. 2000. Draft initial status survey of nonindigenous animals in South Florida. A report by the South Florida Ecosystem Working Group.

Copal, B. and K.P. Sharma. 1981. *Water-Hyacinth (Eichhornia crassipes), Most Troublesome Weed of the World*. Hindasia Publishers, C.C. Colony, Delhi, India.

Gore, R.. 1976. Florida, Noah's ark for exotic newcomers. *National Geographic*, 150 (4): 538-559.

Gowanloch, J.N. 1944. The Economic Status of Water Hyacinth in Louisiana. *La. Conserv*., 2: 3-8.

Hoffstettler, R.H. 1991. The Current Status of *Melaleuca quinquenervia* in Southern Florida. R.F. Doren, ed. In: *Proc. Exotic Pest Plant Symposium*, November 2 through 4, 1988, Miami, FL.

Holm, L.G., D.L. Plucknett and J.P. Herberger. 1977. The World's Worst Weeds: Distribution and Biology. Univ. Press, Honolulu, HI.

Holm, L.G., J.V. Pancho, J.P. Herberger and D.L. Plucknett. 1979. A Geographic Atlas of World Weeds. John Wiley and Sons, New York, NY.

IUCN. 1999. Draft IUCN Guidelines for the Prevention of Biodiversity Loss due to Biological Invasions. February 1999. Invasive Species Specialist Group, Species Survival Commission, International Union for the Conservation of Nature. Online at: http://www.iucn.org/themes/ssc/pubs/policy/invasivesEng.htm.

Jewell, S.P. 1996. *Lygodium microphyllum's* Coverage and Apparent Spread at A.R.M. Marshall Loxahatchee National Wildlife Refuge. Paper Presented to Workshop on Climbing Ferns and Invasive Exotic Vines, Hobe Sound, FL. Available from the South Florida Water Management District, West Palm Beach, FL.

Johnston, M.C. 1971. Revision of *Colubrina asiatica* (Rhamnaceae). *Brittonia*, 23: 2-53.

Jones, D. 1997. Ecological Consequences of Latherleaf (*Colubrina asiatica*) in Southern Florida. *Wildland Weeds*, 1(1).

Jones, D.T. 1996. The Status and Management of Colubrina asiatica (Latherleaf) in Everglades National Park. Technical Report, South Florida Natural Resources Center, Everglades National Park, Homestead, FL.

Klukas, R.W. 1969. Exotic Terrestrial Plants in South Florida with Emphasis on Australian Pine (*Casuarina equisetifolia*). Technical Report. Everglades National Park, Homestead, FL. As cited in Austin, 1978. 8 pp.

Lachner, E.A., C.R. Robins and W.R. Courtenay, Jr. 1970. Exotic Fishes and Other Aquatic Organisms Introduced into North America. *Smithsonian Contributions to Zoology*, 59: 1-29.

Langeland, K. (ed.). 1990. Exotic Woody Plant Control. Circular 912. Institute of Food and Agricultural Sciences, University of Florida, Gainesville, FL.

Langeland, K.A. and K.C. Burks, eds. 1998. Identification and Biology of Non-Native Plants in Florida's Natural Areas. University of Florida, Gainesville, FL.

Langeland, K.A. 1988. Maintenance Control of Water Hyacinths and Water Lettuce on Lake Okeechobee: Answers to Frequently Asked Questions. University of Florida, Gainesville, FL.

Langeland, K.A. and R.K. Stocker. 1997. Control of Non-Native Plants in Natural Areas of Florida. SP 242. University of Florida, Gainesville, FL.

Laroche, F.B. (ed.). 1994. Melaleuca Management Plan for Florida. Task Force Report. Florida Exotic Pest Plant Council, West Palm Beach, FL.

Laroche, F.B. and A.P. Ferriter. 1992. Estimating Expansion Rates of Melaleuca in South Florida. *J. of Aquat. Plant Management*, 30: 62-65.

LaRosa, A.M., R.F. Doren and L. Gunderson. 1992. Alien Plant Management in the Everglades National Park: An Historical Perspective. C.P. Stone, C.W. Smith and J.T. Tunison, eds. In: *Alien Plant Invasions in Native Ecosystems of Hawaii: Management and Research*. University of Hawaii Cooperative National Park Resources Studies Unite. Honolulu, HI.

Long, R.W. and O. Lakela. 1971. *A Flora of Tropical Florida*. University of Miami Press. Coral Gables, FL.

Maithani, G.P., V.K. Bahuguna and P. Lal. 1986. Effect of Forest Fires on the Ground Vegetation of the Moist Deciduous Sal Forest. *India Forester*, 112: 646-667.

Maxwell, L. 1984. *Florida Trees and Palms*. Lewis Maxwell. Tampa, FL.

McCann, J.A., L.N. Arkin and J.D. Williams. 1996. Nonindigenous Aquatic and Selected Terrestrial Species of Florida: Status, Pathway and Time of Introduction, Present Distribution, and Significant Ecological and Economic Effects. Southeastern Biological Science Center, National Biological Service, Gainesville, Florida. Published March 1996 on the Internet by the Center for Aquatic Plants, University of Florida. At: http://aquat1.ifas.ufl.edu/mctitle.html.

Milon, J. Walter and J. Yingling 1986. An Economic Analysis of the Benefits of Aquatic Weed Control in North-Central Florida. University of Florida Institute of Food and Agricultural Sciences, Economics Report 113.

Mitchell, D.S. 1976. The Growth and Management of *Eichhornia crassipes* and *Salvinia* spp. in their Native Environment and in Alien Situations. C.K. Varshney and J.Rzoska, eds. In: *Aquatic Weeds in South East Asia*. Dr. W. Junk b.v., Publishers, The Hague.

Morton, J.F. 1971a. *Exotic Plants*. Golden Press. New York, NY.

Morton, J.F. 1971b. *Plants Poisonous to People in Florida and Other Warm Areas*. Hurricane House, Miami, FL.

Morton, J.F. 1976. Pestiferous Spread of Many Ornamental and Fruit Species in South Florida. *Proc. Fla. State Hort. Soc*., 89: 348-353.

Morton, J.F. 1978. Brazilian Pepper: Its Impact on People, Animals and the Environment. *Econ. Bot*., 32: 353-359.

Morton, J.F. 1980. The Australian Pine or Beefwood (*Casaurina equisetifolia L.*), An Invasive "Weed" Tree in Florida. *Proceedings of the Florida State Hort. Soc*., 93: 87-95.

Myers, R.L. 1975. The Relationship of Site Conditions to the Invading Capability of Melaleuca in Southern Florida. M.S. Thesis, University of Florida, Gainesville, FL.

Mytinger, L. and G.B. Williamson. 1987. The Invasion of *Schinus* into Saline Communities of Everglades National Park. *Florida Scientist*, 50: 7-12.

Nauman, C.F., and D.F. Austin. 1978. Spread of the Exotic Fern *Lygodium microphyllum* in Florida. *Amer. Fern J*., 68: 65-66.

Nelson, G. 1994. *The Trees of Florida*. Pineapple Press Inc. Sarasota, FL.

Nelson, J.B. 1993. Noteworthy Collections: South Carolina. *Castanea*, 58: 59-63.

O'Hare, Nancy K. and G.H. Dalrymple. 1997. Wildlife in Southern Everglades Wetlands Invaded by Melaleuca (*Melaleuca quinquenervia*). *Bull. Fla. Mus. of Nat. Hist*., 41(1): 1-68.

OTA. 1993. Harmful Nonindigenous Species in the United States. OTA-F-565. U.S. Congress, Office of Technology Assessment, Washington, D.C.

Olmsted, I., L. Loope and R. Russell. 1981. Vegetation of the Southern Coastal Region of Everglades National Park between Flamingo and Joe Bay. Report T-260. South Florida Research Center, Everglades National Park, Homestead, FL.

Ostrenko, W. and F. Mazzotti. 1981. Small Mammal Populations in *Melaleuca quinquenervia* Communities in the Eastern Florida Everglades. R.K. Geiger, ed. In: *Proceedings of the*

Melaleuca Symp., Florida. Dept. of Agriculture and Consumer Services, Division of Forestry, Tallahassee, FL.

Pemberton, R. 1998. The Potential of Biological Control to Manage Old World Climbing Fern (*Lygodium microphyllum*), an Invasive Weed in Florida. *American Fern J*., 88(4): 176-182.

Pemberton, R. and A. Ferriter. 1998. Old World Climbing Fern (*Lygodium microphyllum*), A Dangerous Invasive Weed in Florida. *American Fern J*., 88(4): 165-175.

Penfound, W.T. and T.T. Earle. 1948. The Biology of the Water Hyacinth. *Eco. Monog*., 18: 449-472.

Perry, L.M. 1980. *Medicinal Plants of East and Southeast Asia*. MIT Press. Cambridge, MA.

Pimentel, D., L. Lach, R. Zuniga and D. Morrison. 2000. Environmental and Economic Costs of Nonindigenous Species in the United States. *Bioscience,* 50: 53-65.

Roberts, R.E. 1996. The Monster of Hobe Sound. M. Bodle, ed. In: *Proceedings of Invasive Vines Workshop*, West Palm Beach, FL. 35 pp. Available from the South Florida Water Management District, West Palm Beach, FL.

Robertson, W.B., Jr. and P.C. Frederick. 1994. The Faunal Chapters: Contexts, Synthesis, and Departures. S.M. Davis and J.C. Ogden, eds. pp. 709-737. In: *Everglades: The Ecosystem and its Restoration*. St. Lucie Press, Delray Beach, FL.

Rose, M. and R.F. Doren. 1988. Distribution of Melaleuca (*Melaleuca quinquenervia*), Brazilian pepper (*Schinus terebinthifolius*), Australian pine, (*Casuarina* spp.) and Latherleaf (*Colubrina asiatica*) in Everglades National Park. NPS Unpublished Report, Everglades National Park, Homestead, FL.

Russell, R.L., L. Loope and I. Olmsted. 1982. *Colubrina asiatica* in Southern Florida. Technical Report. South Florida Research Center, Everglades National Park, Homestead, FL.

Schardt, J.D. and D.C. Schmitz. 1991. Florida Aquatic Plant Survey, 1990. Technical Report 91-CGA. Florida Department of Natural Resources, Tallahassee, FL.

Schmitz, D.C. and T.C. Brown, 1994. An Assessment of Invasive Nonindigenous Species in Florida's Public Lands. Florida Department of Environmental Protection, Tallahassee, FL.

Schmitz, D.C., J.D. Schardt, A.J. Leslie, F.A. Dray, J.A. Osborne and B.V. Nelson. 1993. The Ecological Impact and Management History of Three Invasive Alien Aquatic Plant Species in Florida. B.N. McKnight, ed. In: *Biological Pollution: The Control and Impact of Invasive Exotic Species*. Indiana Academy of Science, Indianapolis, IN.

Schultz, G.E. 1992. *Colubrina asiatica*. Element Stewardship Abstract. The Nature Conservancy (TNC), Arlington, VA. Available from TNC Office, Florida Museum of Natural History, Gainesville, FL.

Science Coordination Team. 1999. SCT's recommendation for CESI FY2001. September 2, 1999.

SSG. 1996. South Florida Ecosystem Restoration: Scientific Information Needs. Report to the Working Group of the South Florida Ecosystem Task Force, Science Subgroup, West Palm Beach, FL.

Seavey, R. and J. Seavey. An Overview of Shoebutton ardisia (*Ardisia elliptica*) in Everglades National Park through 1993. NPS Unpublished Report, Everglades National Park, Homestead, FL.

Shafland, P.L. 1996. Exotic Fish Assessments: An Alternative View. *Reviews in Fisheries Science*, 4(2): 123-132.

Sharma, B.M. 1984. Ecophysiological Studies on Water Lettuce in a Polluted Lake. *J. of Aquat. Plant Mgmnt*., 22: 19-21.

Simberloff, D. 1996. Impacts of Introduced Species in the United States. *Consequences*, 2(2): 13-22.

Small, J.K. 1927. Among Floral Aborigines: A Record of Exploration in Florida in the Winter of 1922. *J. New York Bot. Gard*., 28: 1-20, 25-40.

Small, J.K. 1933. Manual of the Southeastern Flora, Part One and Two. University of North Carolina Press, Chapel Hill, NC. (Facsimile Reprint 1972, Hafner Publishing, New York, NY.)

SFRPC. 1991. Regional Plan for South Florida. South Florida Regional Planning Council, Hollywood, FL.

SFRPC. 1995. Strategic Regional Policy Plan for South Florida. South Florida Regional Planning Council, Hollywood, FL.

Sowder, A. and S. Woodall. 1985. Small Mammals of Melaleuca Stands and Adjacent Environments in Southwestern Florida. *Florida Sci*., 48(1): 41-44.

Stocker, R.K., A.P. Ferriter, D.D. Thayer, M. Rock and S. Smith. 1997. Old World Climbing Fern: Hitting South Florida Below the Belt. *Wildland Weeds*, 1(1).

Stoddard, A.A. III. 1989. The Phytogeography and Paleofloristics of *Pistia stratiotes L*. *Aquatics*, 11: 21-23.

Stuckey, R.L. and D.H. Les. 1984. *Pistia stratiotes* Recorded from Florida in Bartram's Travels. *Aquaphyte*, 4(6): 1765-1774

Tomlinson, P.B. 1980. *The Biology of Trees Native to Tropical Florida*. Harvard University Printing Office, Allston, MA.

USACE and SFWMD. 1999. Central and Southern Florida Project Comprehensive Review Study Final Integrated Feasibility Report and Programmatic Environmental Impact Study. U.S. Army Corps of Engineers, Jacksonville District, Jacksonville, FL, and South Florida Water Management District, West Palm Beach, FL.

USFWS. 1999. Final Fish and Wildlife Coordination Act Report - Central and Southern Florida Comprehensive Review Study. U.S. Fish and Wildlife Service, South Florida Restoration Office, Vero Beach, FL.

USFWS. 1999. South Florida Multi-Species Recovery Plan. U.S. Fish and Wildlife Service, Atlanta, GA.

USDA. 1997. PLANTS National Database, U.S. Dept. of Agriculture, Natural Resources Conservation Service. Online at: http://plants.usda.gov.

VanDoren, M. (ed.) 1928. *Travels of William Bartram*. Macy-Masius Publishers. Dover Publications, Inc. New York, NY.

Watkins, J.V. 1970. F*lorida Landscape Plants, Native and Exotic*. University of Florida Press, Gainesville, FL.

Wilson, K. 1997. Casuarinaceae R. Brown. In: *Flora of North America North of Mexico, Vol. 3*. Oxford University Press. New York, NY.

Wolverton, B.C. and R.C. McDonald. 1979. Water Hyacinth (*Eichhornia crassipes*) Productivity and Harvesting Studies. *Econ. Botany*, 33: 1-10.

Woodall, S.L. 1981. Site Requirements for Melaleuca Seedling Establishment. R.K. Geiger, ed. In: *Proc. Melaleuca Symposium* (September 23 through 24, 1980). Division of Forestry, Department of Agricultural and Consumer Services, Tallahassee, FL.

Woodall, S.L. 1982. Herbicide Tests for Control of Brazilian Pepper and Melaleuca in Florida. Research Note SE-314. Forest Service, U.S. Department of Agriculture, Washington, D.C.

Woodall, S.L. 1983. Establishment of *Melaleuca quinquenervia* Seedlings in the Pine Cypress Ecotone of Southwest Florida. *Fla. Scientist*, 46: 65-71.

Wunderlin, R.P. 1982. *Guide to the Vascular Plants of Central Florida*. University Presses of Florida, University of South Florida., Tampa, FL.

Wunderlin, R.P., B.F. Hansen and E.L. Bridges. 1995 (updated May 1996). Atlas of Florida Vascular Plants. Online at: http://www.usf.edu/~isb/projects/hb-atlas.html.